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# Assessment of integrated patterns of human-animal-environment health: a holistic and stratified analysis

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## Abstract

**Background** Data-driven research is a very important component of One Health. As the core part of the global One Health index (GOHI), the global One Health Intrinsic Drivers index (IDI) is a framework for evaluating the baseline conditions of human-animal-environment health. This study aims to assess the global performance in terms of GOH-IDI, compare it across different World Bank regions, and analyze the relationships between GOH-IDI and national economic levels.

**Methods** The raw data among 146 countries were collected from authoritative databases and official reports in November 2021. Descriptive statistical analysis, data visualization and manipulation, Shapiro normality test and ridge maps were used to evaluate and identify the spatial and classificatory distribution of GOH-IDI. This paper uses the World Bank regional classification and the World Bank income groups to analyse the relationship between GOH-IDI and regional economic levels, and completes the case studies of representative countries.

**Results** The performance of One Health Intrinsic Driver in 146 countries was evaluated. The mean (standard deviation, SD) score of GOH-IDI is 54.05 (4.95). The values (mean SD) of different regions are North America (60.44, 2.36), Europe and Central Asia (57.73, 3.29), Middle East and North Africa (57.02, 2.56), East Asia and Pacific (53.87, 5.22), Latin America and the Caribbean (53.75, 2.20), South Asia (52.45, 2.61) and sub-Saharan Africa (48.27, 2.48). Gross national income per capita was moderately correlated with GOH-IDI ( $R^2 = 0.651$ , Deviance explained = 66.6%,  $P < 0.005$ ). Low income countries have the best performance in some secondary indicators, including Non-communicable Diseases and Mental Health and Health risks. Five indicators are not statistically different at each economic level, including Animal Epidemic Disease, Animal Biodiversity, Air Quality and Climate Change, Land Resources and Environmental Biodiversity.

**Conclusions** The GOH-IDI is a crucial tool to evaluate the situation of One Health. There are inter-regional differences in GOH-IDI significantly at the worldwide level. The best performing region for GOH-IDI was North America and the worst was sub-Saharan Africa. There is a positive correlation between the GOH-IDI and country economic status, with high-income countries performing well in most indicators. GOH-IDI facilitates researchers' understanding

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of the multidimensional situation in each country and invests more attention in scientific questions that need to be addressed urgently.

**Keywords** One Health, Evaluation framework, Economic disparity, Global One Health index

## Background

The global pandemic of coronavirus disease 2019 (COVID-19) has increased the awareness of the links and interactions between human health, animal health, and environmental health. To address complex health issues, many experts and academics have proposed the concept of "One Health". This approach considers the interconnectedness of human, animal, and environmental health and seeks to improve overall well-being without compromising any of these elements. By studying and managing health in this holistic way, the effectiveness of interventions is enhanced [1, 2].

Many countries and research institutions have different definitions of health and sustainability, deriving many indicator systems related to One Health but fundamentally different. There are currently a variety of datasets related to One Health, including Sustainable Development Goals (SDGs), Gross Domestic Product (GDP), Human Development Index (HDI), Environmental Performance Index (EPI) and Global Burden of Disease [3–9]. In addition, there are a number of exploratory studies of the One Health concept [10–16]; some of them have been carried out as field surveys [12, 13]. A global assessment is important, which could build a large network of mutual trust and promote the spread of the One Health concept. In 2022, a new global One Health assessment framework was developed [17, 18]. Global One Health index (GOHI) consists of three parts: core drivers index, intrinsic drivers index, and external drivers index [17]. However, the antecedent study describes the data holistically and does not discuss the intrinsic drivers index in detail [17]. The Intrinsic drivers index assesses the actual situation at this stage across regions and countries, making society aware of the pressing socio-economic issues of the day and promoting the implementation and development of the One Health action. Therefore, we conducted this study and accomplished data stratification and analyze using the socioeconomic factor Gini coefficient.

Global One Health Intrinsic Drivers index (GOH-ID) focuses more on the interface of human health, animal health and ecosystem diversity, and environmental health [19]. "Intrinsic" represents the outcome indicator in the GOHI. Traditional indicator systems generally contain three components, including structure (stable components of the system), process (interventions on the system), and outcome (impact of the indicator on the system) [20, 21]. A separate assessment of outcome

indicators and intervention indicators is more conducive to researchers and policymakers to understand the implications of the data [1, 8, 22, 23].

In earlier studies, our team developed the framework and weights of GOH-ID, which accomplished by the same key members used grounded theory (GT) method, fuzzy analytical hierarchy process (FAHP) and entropy weight method (EWM) to construct the indicators and calculate the weights of GOH-ID [19]. This study described Global distribution of GOH-ID, analyzed correlation between GOH-ID score and Gini coefficient and made policy recommendations in the perspective of global realities and typical case discussions.

## Methods

### Data collection and resources

The raw data collection and calculation was constructed in five steps, including framework formulation, indicator selection, database building, weight determination and GOHI scores calculation [17, 18]. The data related to the GOH-ID project is stored in GitHub (<https://github.com/DayuGuo/G2-IDI>). GOH-ID's database consists of 13 open sources and reliable databases (Table 1) [17, 18].

### GOH-ID framework overview

Our team have established a scientific standard to evaluate the intrinsic drivers and a scientific standard to measure the development level in different regions for One Health [19]. The specific procedure for the construction and score calculation of the GOH-ID framework has been published and is organized in Additional file 1 and Additional file 2 [17, 18]. The indictor scheme for GOH-ID compose of three first-level indicators, 15 second-level indicators, 61 third-level indicators. Additional file 1 contains the detailed indicators and weights of GOH-ID [19].

### Visualization analysis

Version control of all data in this project is hosted on GitHub Desktop 2.9.11 (GitHub Incorporated, USA). Data and algorithms are open sources (<https://github.com/DayuGuo/OHI-IDI-Animal-Environmental>). Data were analyzed using R studio 2021.09.1 (Posit Software, Boston, USA), R version 4.1.2 (Lucent Technologies, Jasmine Mountain, USA). R Packages used in the analyze include tidyverse, ggrepel, ggplot2, cowplot,

**Table 1** Main database

Dimension	Database	Source
Human Health	SDGs Dashboard	<a href="https://dashboards.sdgindex.org/">https://dashboards.sdgindex.org/</a>
	WHO	<a href="https://www.who.int/data">https://www.who.int/data</a>
	IHME-GBD	<a href="https://www.healthdata.org/gbd/2019">https://www.healthdata.org/gbd/2019</a>
Animal Health and Ecosystem Diversity	EMPRES-I	<a href="https://empres-i.apps.fao.org/">https://empres-i.apps.fao.org/</a>
	OIE-WAHIS	<a href="https://wahis.woah.org/#/home">https://wahis.woah.org/#/home</a>
	Environmental Performance Index	<a href="https://epi.yale.edu/">https://epi.yale.edu/</a>
Environmental Health	Our World in Data	<a href="https://ourworldindata.org/">https://ourworldindata.org/</a>
	World Bank	<a href="https://data.worldbank.org/indicator">https://data.worldbank.org/indicator</a>
	State of Global Air	<a href="https://www.stateofglobalair.org/">https://www.stateofglobalair.org/</a>
	Global Climate Risk Index	<a href="https://www.germanwatch.org/en/crisis">https://www.germanwatch.org/en/crisis</a>
	Environmental Performance Index	<a href="https://epi.yale.edu/">https://epi.yale.edu/</a>
	Our World in Data	<a href="https://ourworldindata.org/">https://ourworldindata.org/</a>
	SDGs Dashboard	<a href="https://dashboards.sdgindex.org/">https://dashboards.sdgindex.org/</a>

EMPRES-/Emergency Prevention Programme for Transboundary Animal Diseases, OIE-WAHIS OIE World Animal Health Information System

ggstatsplot, palmerpenguins, readr, and esquisse. Methods of data analyze, and evaluation include descriptive statistics, data visualizations and data shaping. Heat maps are used to assess differences between indicators at each level. To observe the differences between regions and countries across the globe, we mapped the spatial distribution using ArcGIS 10.5 (ESRI, Redlands, USA). The Shapiro normality test is used to test whether the data is normally distributed. GOH-IDI data used in this paper are normally distributed, so means and standard deviations (*SD*) are used, and GraphPad Prism 9.3.1 (Graphpad Software Incorporated, USA) is used for those graphs. To analyze the data at a hierarchical level, we have used data from the World Bank database (<https://data.worldbank.org/indicator>). Gross national income (GNI) per capita (Atlas method) is used because it is an internationally accepted and comparable indicator. Generalized Additive Models (GAM) were used to analyze the relationship between GOH-IDI and GNI per capita. The country with the highest score in each World Bank income level was selected for case studies. The data analyze of the case studies was done through Excel Version 2107 (Microsoft Windows, USA). Countries in different geographical regions have different economic profiles. Its economic level determines a country's resources dedicated to governance. Analyzing the current situation of each country in conjunction with the economic level and GOH-IDI performance can lead to more effective strategies. The World Bank assigns the world's economies to four income groups based on GNI per capita, including high income countries (HICs), upper middle income countries (UMICs), lower middle income countries (LMICs)

and low income countries (LICs) (see Additional file 2 for details).

## Results

### Global distribution of GOH-IDI scores

A total of 146 countries worldwide were included in this study, of which 19 were in East Asia and Pacific, 47 were in Europe and Central Asia, 18 were in Latin America and the Caribbean, 16 were in Middle East and North Africa, 16 were in Middle East and North Africa, 2 were in North America, 7 were in South Asia, and 37 were in sub-Saharan Africa (see Additional file 2 for details). The mean (*SD*) score of GOH-IDI is 54.05 (4.95), the lowest score is 44.11 and the highest score is 64.51 (Fig. 1). The mean (*SD*) score of Human Health is 52.73 (6.79). The mean (*SD*) score of Animal Health and Ecosystem Diversity is 57.68 (6.54). The mean (*SD*) score of Environmental Health is 51.74 (5.61).

The Shapiro–Wilk normality test proved that the GOH-IDI score profile fits a normal distribution ( $W=0.981$ ,  $P=0.047$ ), as do human health and environmental health. The animal health section has many qualitative indicators unsuitable for normal distribution analyze (Fig. 2).

Global distribution of scores of GOH-IDI is illustrated in Fig. 3. This study includes two countries in North America, the scores of these two countries are ranked between 1 and 30. Most of the sub-Saharan Africa (SSA) countries (59.5%) rank between 121 and 146. The highest-scoring country in SSA is Senegal (53.56), and the lowest score is Cote d'Ivoire (44.11). The highest-scoring country in North America is Canada (62.10), and the lowest is the United States of America (58.77). The highest-scoring country in South Asia is Bhutan (56.09), and

Country	Rankings																			
	Human Health			B.1.1 Reproductive, Maternal, New-born and Child Health			B.1.2 Infectious Diseases			B.1.3 Non-communicable Diseases and Mental Health			B.1.4 Injuries and Violence			B.1.5 Universal Health Coverage and Health Systems			B.1.6 Health Risk	
Afghanistan	47	10	58	67	32	33	88	56	87	42	20	39	49	47	82	52	12	51	51	
Albania	56	58	82	45	48	52	42	55	86	18	25	46	51	43	57	59	45	53	54	
Algeria	55	42	83	69	35	52	36	49	93	30	23	16	54	44	76	51	47	54	53	
Argentina	50	48	68	39	40	52	47	57	87	24	78	29	51	58	50	57	40	48	53	
Armenia	54	55	74	44	39	56	49	54	82	32	38	37	51	44	64	62	30	53	53	
Australia	63	81	90	41	62	72	19	62	83	31	71	50	62	68	42	61	73	67	63	
Austria	58	86	80	27	61	60	19	64	88	24	75	50	62	58	58	58	73	68	61	
Azerbaijan	51	41	75	49	45	41	55	63	95	17	31	59	53	39	80	49	46	51	56	
Bahrain	62	70	66	67	60	56	47	68	95	38	48	59	49	18	59	60	60	51	60	
Bangladesh	51	23	54	61	45	48	83	62	93	51	4	51	44	44	47	66	10	47	52	
Barbados	50	50	83	35	38	52	30	61	96	32	55	37	53	65	47	48	43	57	55	
Belarus	56	89	63	36	36	67	28	61	81	43	55	48	55	46	70	56	45	58	57	
Belgium	59	89	76	31	54	65	23	61	87	9	74	48	59	61	57	50	69	58	59	
Belize	56	44	73	60	39	62	50	61	93	23	47	46	49	45	48	69	16	64	55	
Benin	44	9	46	66	23	36	86	63	95	44	10	52	42	34	60	39	19	61	50	
Bhutan	57	35	67	50	49	65	74	58	87	40	20	46	54	30	76	78	18	67	56	
Bolivia	49	29	63	45	33	67	56	56	86	41	48	32	51	55	43	63	25	64	52	
Botswana	47	27	45	45	24	71	66	59	89	35	29	45	50	38	52	50	34	80	52	
Brazil	45	42	54	46	37	46	44	57	69	34	72	47	53	61	48	64	38	53	52	
Brunei Darussalam	58	60	77	55	66	58	25	52	55	37	40	58	53	48	61	60	41	52	54	
Bulgaria	51	64	72	21	49	56	34	61	91	35	42	44	51	41	55	57	49	55	54	
Burkina Faso	50	10	57	75	13	54	86	53	81	33	2	46	42	34	70	28	22	58	48	
Burundi	51	16	51	71	12	58	97	47	72	34	29	30	45	51	59	37	23	55	48	
Cabo Verde	53	39	66	54	29	67	56	46	53	37	31	45	52	62	75	53	28	40	50	
Cambodia	54	30	58	58	39	58	81	56	83	36	18	46	43	50	58	46	23	36	51	
Cameroon	41	9	37	66	20	35	85	53	91	44	5	29	49	37	62	64	23	59	48	
Canada	61	77	87	39	53	72	20	62	92	33	81	36	63	62	53	66	71	64	62	
Central African Republic	34	1	26	54	10	26	98	51	80	35	15	37	49	31	69	50	29	66	45	
Chad	42	1	47	75	12	26	94	49	70	37	4	47	42	22	64	38	28	59	44	
Chile	54	60	69	46	41	63	36	59	92	43	76	21	55	61	40	70	38	63	56	
China	57	68	77	38	40	58	47	60	97	35	41	35	46	38	47	66	30	50	54	
Colombia	48	40	53	61	39	65	22	63	96	46	61	32	57	66	58	66	33	59	56	
Costa Rica	54	51	68	52	44	73	24	61	95	39	58	34	52	51	59	65	27	57	56	
Cote d'Ivoire	43	5	41	69	18	44	83	49	87	38	9	23	41	44	55	42	19	42	44	
Croatia	54	79	78	16	56	56	30	66	91	44	47	53	56	48	61	62	53	59	59	
Cuba	57	61	69	30	51	70	53	60	89	30	40	47	52	55	42	56	44	60	56	
Cyprus	60	94	70	48	54	54	27	56	84	36	64	30	52	47	57	50	63	45	56	
Czech Republic	59	87	78	26	53	64	36	64	85	43	69	48	57	51	57	52	63	62	60	
Dem. Rep. Congo	41	7	40	67	13	32	93	52	87	39	26	26	45	49	45	40	29	60	46	
Denmark	62	87	84	29	64	69	29	64	86	27	68	54	60	63	56	49	77	58	62	
Dominican Republic	47	26	63	54	20	62	49	56	91	42	46	25	47	50	46	52	37	49	50	
Ecuador	50	41	66	57	37	51	43	64	82	33	70	53	50	53	53	62	22	57	55	
Egypt	56	40	87	59	41	47	57	53	90	37	36	22	56	40	73	66	40	62	55	
Estonia	54	90	67	32	49	58	11	68	93	43	73	48	56	48	62	57	60	57	59	
Ethiopia	46	15	47	75	15	35	89	50	90	34	15	23	44	47	71	29	16	59	47	
Fiji	45	39	43	34	41	58	59	65	92	53	57	41	53	59	55	61	30	56	54	
Finland	61	95	89	40	53	60	11	59	75	34	77	45	59	58	47	60	74	55	59	
France	58	83	75	33	55	65	23	59	86	40	69	33	63	66	60	54	74	61	60	
Gabon	41	18	37	63	29	40	63	46	93	32	21	8	57	40	62	66	73	44	66	
Georgia	50	54	59	27	43	60	48	62	92	31	32	52	50	42	66	64	20	57	54	

**Fig. 1** Performance on GOH-ID. Countries are listed in alphabetical order, and are divided into five ranking groups. The numbers in Fig. 1 represent the scores of each country, and the depth of color represents the ranking of the country for that score. The raw data information contained in each indicator is shown in the Additional files 1, 2, 3. GOH-ID Global One Health Intrinsic Driver Index

Country	Rankings																		
	Human Health		B.1.1 Reproductive, Maternal, New-born and Child Health		B.1.2 Infectious Diseases		B.1.3 Non-communicable Diseases and Mental Health		B.1.4 Injuries and Violence		B.1.5 Universal Health Coverage and Health Systems		B.1.6 Health Risk		Animal Health and Ecosystem Diversity				
Germany	61	83	85	28	59	71	25	64	88	19	77	50	60	64	53	51	73	63	61
Ghana	46	18	41	66	21	55	76	55	93	34	12	36	46	51	48	50	20	57	49
Greece	58	87	80	31	58	57	21	56	89	37	39	32	58	60	54	59	62	53	57
Guinea	40	4	41	68	20	25	93	54	81	35	22	42	41	41	46	46	22	51	45
Honduras	54	38	70	65	28	56	56	53	82	40	50	27	49	54	57	60	26	42	52
Hungary	53	74	77	17	52	54	36	69	95	39	75	51	52	44	59	49	55	52	58
Iceland	64	95	87	45	52	67	19	61	89	25	63	45	65	58	74	67	48	76	63
India	47	36	48	43	45	37	83	57	80	44	29	44	44	34	42	75	19	47	49
Indonesia	50	32	57	51	45	43	76	62	97	36	29	44	47	62	47	55	22	44	53
Iran	57	50	80	61	30	68	36	56	94	38	46	23	57	54	66	61	49	56	57
Iraq	51	30	72	77	37	44	39	56	85	16	25	51	53	39	69	68	29	57	53
Ireland	62	87	80	46	59	70	14	61	83	23	66	51	60	57	60	56	68	62	61
Israel	63	87	73	52	70	64	22	53	86	35	59	21	54	46	71	43	67	47	57
Italy	59	92	78	27	61	64	18	60	99	28	77	24	58	59	58	56	61	57	59
Japan	65	97	84	30	67	76	23	65	78	31	88	57	56	68	44	54	64	51	62
Jordan	59	47	78	84	42	66	26	61	92	27	30	52	57	51	85	46	45	57	59
Kazakhstan	53	60	72	39	34	58	44	64	99	35	52	41	47	33	49	53	48	55	55
Kenya	51	18	48	76	19	58	85	55	97	35	38	23	47	59	66	28	22	56	51
Kyrgyzstan	56	41	68	66	40	62	50	61	94	39	44	39	49	50	59	57	18	58	55
Laos	48	21	60	53	30	47	81	46	69	42	20	30	41	53	43	60	12	31	45
Latvia	50	75	67	22	39	56	28	67	95	28	61	53	56	51	54	59	60	56	58
Lebanon	57	64	69	59	40	64	36	62	88	36	44	50	55	62	69	51	45	44	58
Lesotho	37	6	48	22	17	49	86	60	85	44	29	49	48	50	74	43	22	49	49
Liberia	41	3	37	79	12	38	83	48	52	33	23	58	46	53	56	53	24	39	45
Libya	55	59	64	70	35	50	43	57	90	33	24	42	53	45	60	57	46	56	55
Lithuania	51	82	63	23	36	57	29	68	92	35	68	55	55	46	57	56	57	59	58
Luxembourg	60	93	74	42	61	63	16	47	49	28	73	45	64	56	76	51	73	68	57
Madagascar	43	15	40	67	18	27	99	57	82	36	23	49	41	61	60	35	22	21	47
Malawi	48	15	34	76	15	62	87	52	88	38	23	27	50	66	62	35	24	62	50
Malaysia	56	62	68	56	35	56	46	53	80	35	77	22	45	53	49	62	31	24	51
Mali	46	3	51	76	22	38	87	41	72	36	8	20	49	43	68	54	24	59	45
Malta	57	71	76	33	61	69	26	66	91	36	64	52	54	57	81	41	51	44	59
Mauritania	46	8	55	83	26	37	70	62	91	34	19	19	56	45	44	61	36	23	59
Mauritius	47	45	78	25	40	56	30	46	56	30	44	42	54	63	80	54	34	33	49
Mexico	48	44	70	49	32	43	42	66	94	35	64	50	50	50	48	58	42	49	55
Moldova	55	51	69	54	47	65	34	61	88	30	39	51	51	50	80	43	39	45	56
Mongolia	52	46	64	52	23	64	52	63	98	34	17	50	48	40	48	62	25	62	54
Montenegro	53	90	60	29	47	53	27	61	82	30	52	53	50	41	52	59	41	56	54
Morocco	54	39	82	46	41	52	56	57	90	33	35	36	53	50	67	50	39	59	55
Mozambique	40	8	26	58	14	46	90	57	86	36	41	37	50	65	53	34	28	66	49
Myanmar	47	25	53	46	32	49	78	58	89	36	44	37	46	54	39	61	24	46	50
Namibia	43	23	36	57	18	59	68	38	74	8	34	12	53	39	64	49	35	79	45
Nepal	51	24	63	51	32	44	93	44	86	45	14	6	57	37	83	83	21	58	51
Netherlands	61	88	78	35	67	67	23	66	99	19	66	50	56	57	53	48	75	52	61
New Zealand	62	74	91	39	56	72	25	53	87	29	56	23	63	62	57	66	63	65	59
Nicaragua	54	35	67	55	41	82	36	59	91	39	47	35	49	57	56	54	34	39	54
Niger	48	7	50	78	17	45	94	62	91	37	25	52	50	43	89	40	15	63	53
Nigeria	41	2	37	86	23	29	76	46	76	41	17	22	47	35	56	60	31	56	45
North Macedonia	52	71	62	19	45	56	54	45	49	20	38	53	50	46	51	57	45	53	49
Norway	66	96	88	41	63	73	17	65	91	37	65	48	63	53	55	66	70	71	65

**Fig. 1** continued

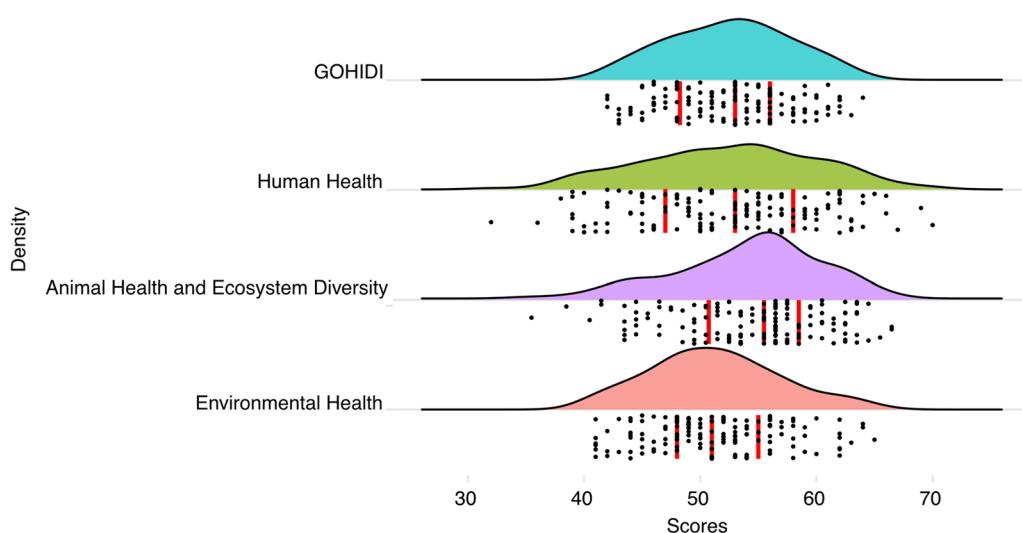
Country	Human Health															Global One Health											
	B.1.1 Reproductive, Maternal, New-born and Child Health	B.1.2 Infectious Diseases	B.1.3 Non-communicable Diseases and Mental Health	B.1.4 Injuries and Violence	B.1.5 Universal Health Coverage and Health Systems	B.1.6 Health Risk	Animal Health and Ecosystem Diversity					B.2.1 Animal Epidemic Disease	B.2.2 Animal Welfare, Relevant Regulations	B.2.3 Animal Nutritional Status	B.2.4 Animal Biodiversity	Environmental Health					B.3.1 Air Quality and Climate Change	B.3.2 Land Resources	B.3.3 Sanitation and Water Resources	B.3.4 Hazardous Chemicals	B.3.5 Environmental biodiversity	Intrinsic Drivers Index	
Rankings	1–30	31–60	61–90	91–120	121–146																						
Oman	62	62	84	76	52	49	39	69	82	44	27	79	52	37	69	51	43	60	61								
Pakistan	46	19	61	46	34	39	79	62	93	35	38	47	48	42	65	57	24	50	52								
Papua New Guinea	43	24	35	46	34	33	97	54	87	44	11	35	47	66	43	36	22	62	48								
Paraguay	52	33	67	55	38	61	51	61	93	19	52	45	49	57	59	62	34	28	54								
Peru	55	43	59	70	37	69	44	61	91	52	49	36	54	57	45	67	33	63	57								
Philippines	48	31	53	54	45	42	70	59	90	42	50	33	52	69	62	55	29	38	53								
Poland	56	83	74	28	52	57	33	58	88	27	78	30	52	42	50	55	53	63	55								
Portugal	55	83	71	23	56	65	23	57	89	47	57	26	56	64	48	54	62	51	56								
Qatar	64	74	75	84	54	42	45	60	85	37	31	51	47	20	44	66	55	52	57								
Republic of Korea	66	90	72	54	60	68	38	58	91	32	60	33	52	50	40	56	67	50	59								
Romania	52	61	72	30	40	55	42	56	84	22	48	41	54	49	61	54	53	55	54								
Russia	53	69	71	30	26	59	45	56	96	25	62	22	57	55	48	64	51	64	55								
Rwanda	52	27	47	70	18	63	86	54	83	33	33	37	47	51	63	37	26	57	51								
Saudi Arabia	61	72	84	71	27	57	38	59	81	36	36	53	54	25	79	69	40	59	58								
Senegal	49	18	51	73	27	49	79	62	86	36	25	59	49	48	54	53	25	63	54								
Serbia	54	72	66	17	55	65	42	60	76	39	52	55	49	41	55	52	43	54	54								
Seychelles	49	42	63	39	47	56	46	43	49	37	49	37	53	54	69	56	45	40	49								
Sierra Leone	42	3	31	69	13	52	86	63	88	44	28	54	41	54	34	43	22	47	48								
Singapore	69	95	81	65	75	66	25	67	85	53	72	51	53	44	56	43	79	46	63								
Slovakia	57	71	77	39	52	62	26	67	97	36	64	47	59	51	69	55	59	60	61								
Slovenia	59	96	69	29	63	63	25	66	86	40	75	51	60	40	78	60	60	64	62								
South Africa	43	29	40	38	16	65	63	58	80	35	74	37	49	53	43	50	39	59	50								
Spain	58	89	73	34	59	69	11	53	93	37	67	10	59	61	52	52	70	59	57								
Sri Lanka	54	60	80	32	40	59	43	62	97	36	37	40	52	61	65	48	28	54	56								
Sudan	49	16	59	75	21	49	69	49	86	31	34	20	48	50	67	33	33	57	48								
Sweden	61	94	78	31	61	74	15	65	89	29	76	50	60	61	44	59	76	58	62								
Switzerland	61	88	79	38	66	62	20	65	88	30	63	53	65	60	69	56	75	69	63								
Tajikistan	58	37	71	66	38	63	67	60	83	33	52	49	50	38	69	61	21	59	56								
Tanzania	46	12	38	80	20	45	85	58	92	34	13	44	48	52	64	34	23	68	51								
Thailand	55	52	69	41	37	67	54	60	87	31	59	42	49	50	47	61	39	47	54								
Timor-Leste	52	28	51	67	45	55	72	40	45	59	10	37	51	43	81	46	27	57	48								
Togo	45	12	46	68	20	42	84	55	80	35	20	47	45	36	65	41	27	58	48								
Trinidad and Tobago	52	42	81	41	58	54	34	40	51	35	60	22	57	50	49	58	49	49	78	50							
Tunisia	55	52	72	58	38	63	37	59	85	43	45	40	54	46	65	54	53	51	56								
Turkey	59	58	74	54	48	66	47	55	80	32	60	36	54	49	56	65	51	47	56								
Turkmenistan	58	42	83	68	37	60	49	59	77	46	40	51	53	54	74	47	35	55	57								
Uganda	47	15	36	81	17	50	85	56	75	35	32	51	48	51	67	37	27	59	50								
Ukraine	49	60	60	36	32	55	39	61	92	33	62	36	51	53	62	50	42	48	54								
United Arab Emirates	69	80	90	78	51	51	53	61	91	34	38	47	53	35	72	48	60	56	61								
United Kingdom	60	77	73	41	62	73	21	64	95	33	74	38	62	65	59	52	75	63	62								
United States of America	54	66	76	29	40	75	19	64	95	31	89	36	58	56	58	57	70	53	59								
Uruguay	50	57	66	23	34	70	37	53	90	33	49	22	51	55	58	62	31	44	51								
Uzbekistan	60	48	79	62	40	64	56	67	89	38	69	52	44	35	56	52	29	48	48								
Viet Nam	51	44	72	37	19	64	58	51	80	40	58	20	42	53	34	60	21	38	48								
Zambia	47	14	29	76	27	56	85	50	80	36	30	27	45	49	42	41	16	75	47								
Zimbabwe	43	13	32	56	14	57	87	57	87	37	35	38	43	61	34	30	21	68	48								

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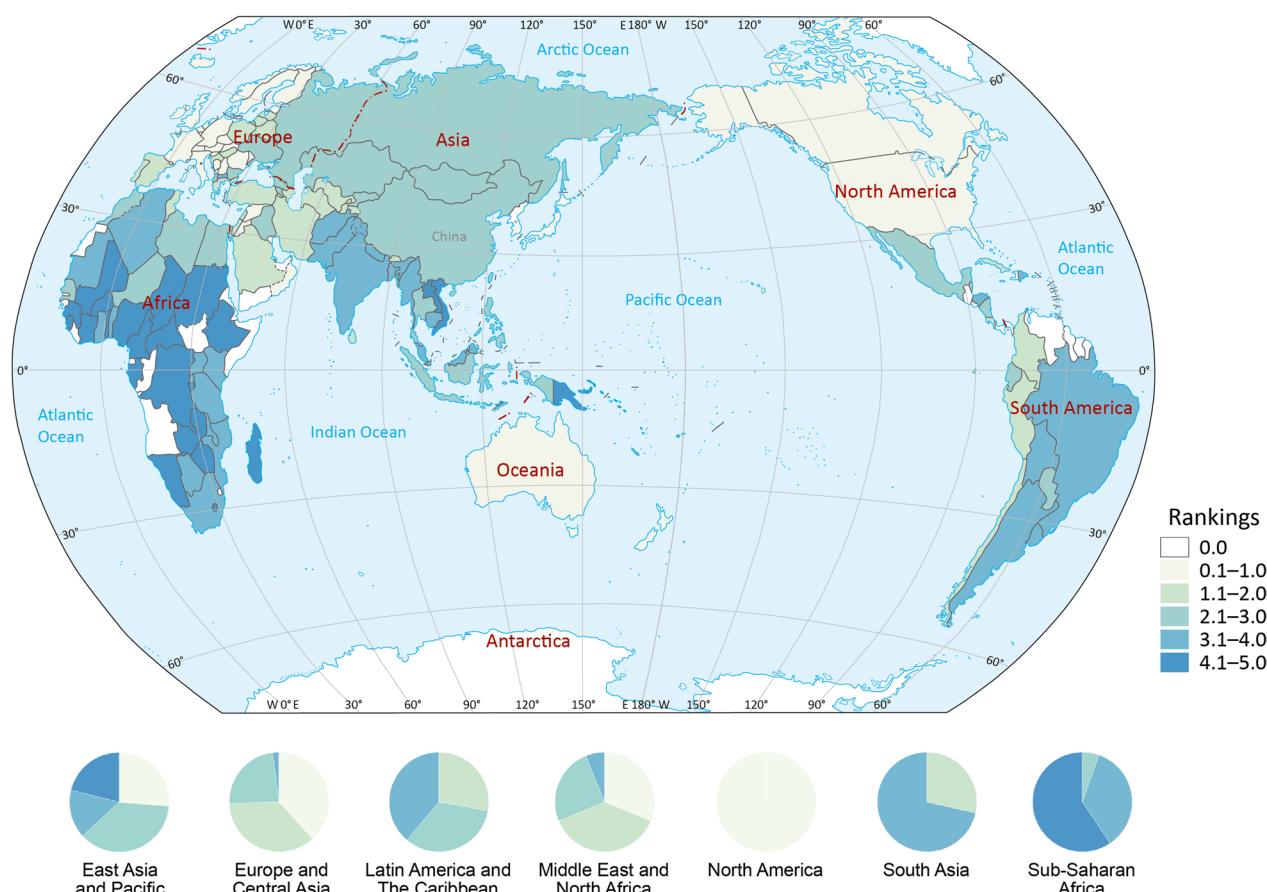
**Fig. 1** continued

the lowest is India (49.36). The highest-scoring country in the Middle East and North Africa is the United Arab Emirates (61.15), and the lowest is Algeria (52.74). In Latin America and the Caribbean, the country with the

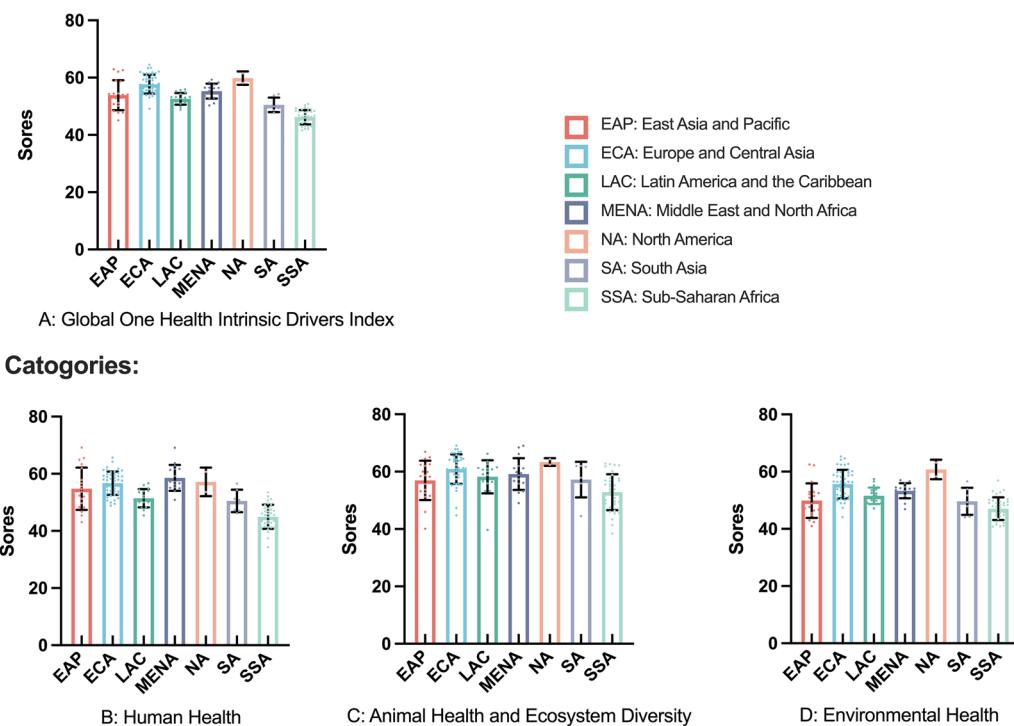
highest score is Peru (56.64), and the lowest score is Trinidad and Tobago (49.56). The highest-scoring country in East Asia and Pacific is Singapore (62.88), and the lowest is Laos (45.10). Among Europe and Central Asia, the



**Fig. 2** Dimensional Distribution of GOH-ID. Three red lines in each ridge map corresponds to the first, second, and third quartile. The black dots represent the distribution of scores, with more dots indicating more countries with that score. GOH-ID/ Global One Health Intrinsic Driver Index



**Fig. 3** Regional rankings map of GOH-ID. Heat map (Fig. 1) and spatial distribution (Fig. 3) were divided into five groups by score ranking with the same criteria. The numbers in Fig. 1 represent the scores of each country, and the depth of color represents the ranking of the country for that score. The pie charts represent the distribution of GOH-ID scores within each region. The raw data information contained in each indicator is shown in the Additional files 1, 2, 3. GOH-ID/ Global One Health Intrinsic Driver Index



**Fig. 4** Mean ( $SD$ ) of GOH-IDI and Categories scores between regions. Note: The different bar chart colors represent different regions. The error line represents the standard deviation. The dots represent the distribution of the data and correspond to the vertical coordinates. Detailed data are listed in Additional file 2. Descriptive analyze are listed in Additional file 3. GOH-IDI Global One Health Intrinsic Driver Index,  $SD$  standard deviation

highest-scoring country is Norway (64.51), and the lowest is North Macedonia (49.17) (Fig. 3).

In the World Bank regional classification, the mean ( $SD$ ) values of GOH-IDI scores by region are (high to low): North America is 60.44 (2.36); Europe and Central Asia is 57.73 (3.29); Middle East and North Africa is 57.02 (2.56); East Asia and Pacific is 53.87 (5.22); Latin America and the Caribbean is 53.75 (2.20); South Asia is 52.45 (2.61); SSA is 48.27 (2.48). SSA mean scores are statistically different from all six other regions, and more significant in the Human Health section ( $P < 0.05$ ). The mean ( $SD$ ) of SSA in Human Health is 44.94 (4.20) (Fig. 4).

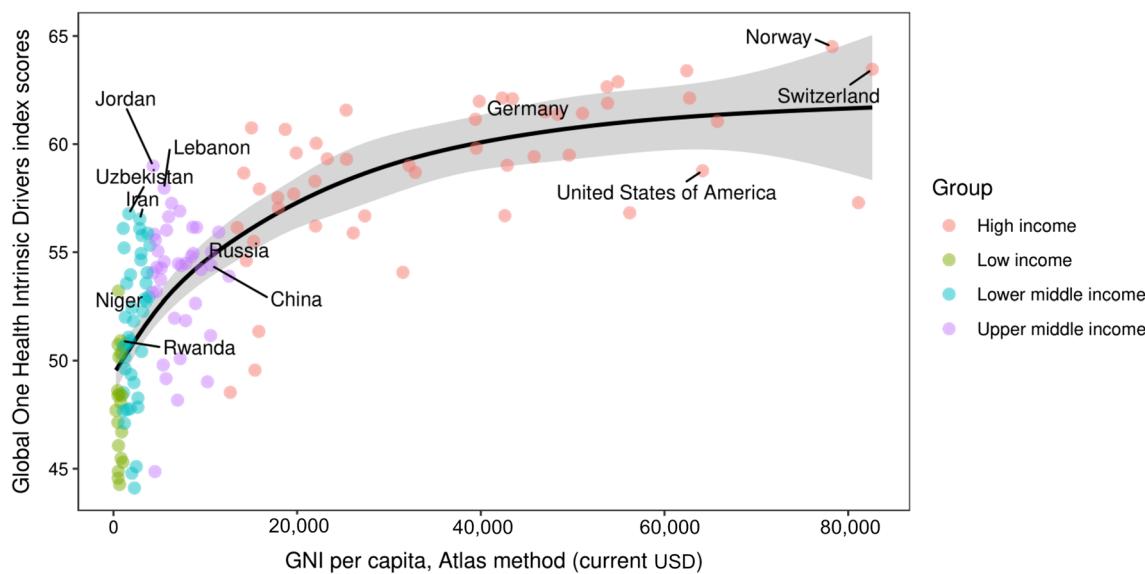
#### Relationship between GOH-IDI scores and economic factors

In the correlation analyze section, GNI per capita was moderately correlated with GOH-IDI by GAM,  $R^2 = 0.651$ , Deviance explained = 66.6%,  $P < 0.005$  (Fig. 5).

A total of 146 countries worldwide were included in this study, of which 19 were LICs, 41 were LMICs, 38 were UMICs, 48 were HICs. The mean ( $SD$ ) values of GOH-IDI scores by World Bank income groups are (high to low): HICs are 58.86 (3.42); UMICs are 53.82 (2.90); LMICs are 51.49 (3.42); LICs are 47.86 (2.46). All four data sets were statistically different (Fig. 6).

The LICs-HICs and LMICs-HICs were statistically significant differences in the Human Health, Animal Health and Environmental Health score profiles (Fig. 6) ( $P < 0.01$ ). In GOH-IDI, the highest country of each different World Bank group is Norway (64.51), Jordan (58.99), Uzbekistan (56.78) and Niger (53.21). In GOH-IDI-Human Health, the highest country among each different World Bank group is Singapore (69.17), Jordan (59.20), Uzbekistan (59.68) and Rwanda (52.09). In GOH-IDI-Animal Health, the highest country of each different World Bank group is Hungary (69.12), Mexico (66.25), Uzbekistan (66.53) and Sierra Leone (62.62). In GOH-IDI-Environmental Health, the highest country of each different World Bank group is Switzerland (65.28), Colombia (57.42), Iran (57.03) and Malawi (50.37).

The statistical differences between the four World Bank income groups are shown in Fig. 7. Five key indicators are not statistically different under the four World Bank groups, including B.1 Animal Epidemic Disease, B.4 Animal Biodiversity, C.1 Air Quality and Climate Change, C.2 Land Resources and C.5 Environmental Biodiversity. Most of the critical indicators had the highest scores for HICs, while A.3 Non-communicable Diseases and Mental Health and A.6 Health Risk had the lowest scores for HICs and the highest scores for LICs (Fig. 7). Nigeria



**Fig. 5** Correlation analyze of GNI per capita and GOH-IDI scores. The World Bank income group is distinguished by four colors (see Additional file 2 for details). Correlation analyze GOH-IDI scores and GNI per capita, Atlas method (current USD). GNI Gross national income, GOH-IDI Global One Health Intrinsic Driver Index

performs best in Non-communicable Diseases and Mental Health (85.73). Madagascar performs best in Health risk (99.35).

## Discussion

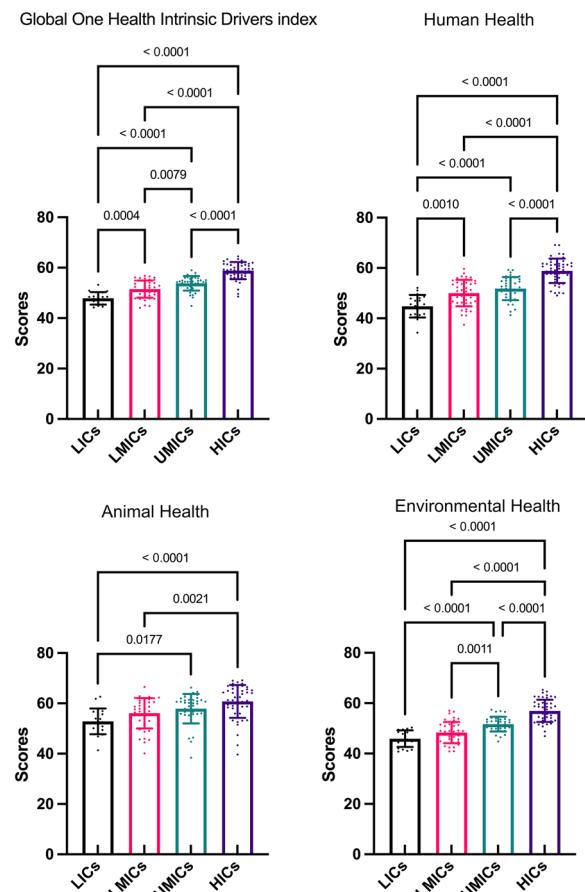
This study analyses the performance of GOH-IDI from multiple organizations from a multidisciplinary perspective to provide the first objective assessment of 146 countries worldwide on the three dimensions of One Health performance. The primary indicators of Human Health, Environmental Health and Animal Health are equally weighted, reflecting the One Health philosophy's emphasis on animal health and ecology. Such a structure also facilitated the identification of problems at a systemic level during this study. This project is based on an authoritative database and optimized by expert consultation and scientific algorithms. This study shows that GOH-IDI is statistically correlated with economic performance (GNI per capita).

HICs countries are more probably to have higher scores in Human Health. LICs countries performed poorly in Reproductive, Maternal, Newborn and Child Health. However, HICs countries performed worse in terms of Health Risk and Non-communicable Disease and Health risk. LICS countries performed worse in Hazardous Chemicals, Reproductive, maternal, newborn and child health and Animal Nutritional Status. These indicators are dependent on national policies and complete industrialization systems. Five indicators are not statistically different between regions at each World Bank

income group, including Animal Epidemic Disease, Animal biodiversity, Air quality and Climate Change, Land Resources and Environmental Biodiversity. These indicators may require global policy guidance and concerted efforts to improve climate change and air quality.

Countries in the same World Bank income groups have similar economic and development statuses. Countries with high GOH-IDI scores in each group could function as a model. There are objective differences in GOH-IDI scores between World Bank income groups. However, it is difficult to see the characteristics of these countries from the data only, and an in-depth understanding of their governance systems is needed. Based on the three-level data, the strengths and weaknesses of each country could be analyzed.

(1) Niger has the best GOH-IDI performance in LICs. Niger's great performance may be attributed to its three well-performing second-level indicators, including Non-communicable Diseases and Mental Health, Health Risk, and Land Resources (Fig. 1). Niger focuses on health policies at the national level [24, 25], has a pilot study based on One Health and values the positive effect of systematic research on policy development [26, 27]. The specificity of Niger's performance in GOH-IDI deserves more research analyze and discussion. (2) Uzbekistan has the best GOH-IDI performance in LMICs. Uzbekistan's overall performance in Human Health and Animal Health was great, especially for the three second-level indicators, including Infectious Diseases, Animal Welfare, Relevant Regulations and Policy Support, and Animal Nutritional



**Fig. 6** Mean (SD) of GOH-IDI and Categories scores in different World Bank income groups. The different colors of the bar chart represent different regions. The error line represents the standard deviation. The dots represent the distribution of the data and correspond to the vertical. Detailed data are listed in Additional file 2. Descriptive analyze are listed in Additional file 3. SD Standard deviation, GOH-IDI Global One Health Intrinsic Driver Index, LICs Low-income countries, LMICs Lower middle-income countries, UMICs Upper middle-income countries, HICs High income-countries

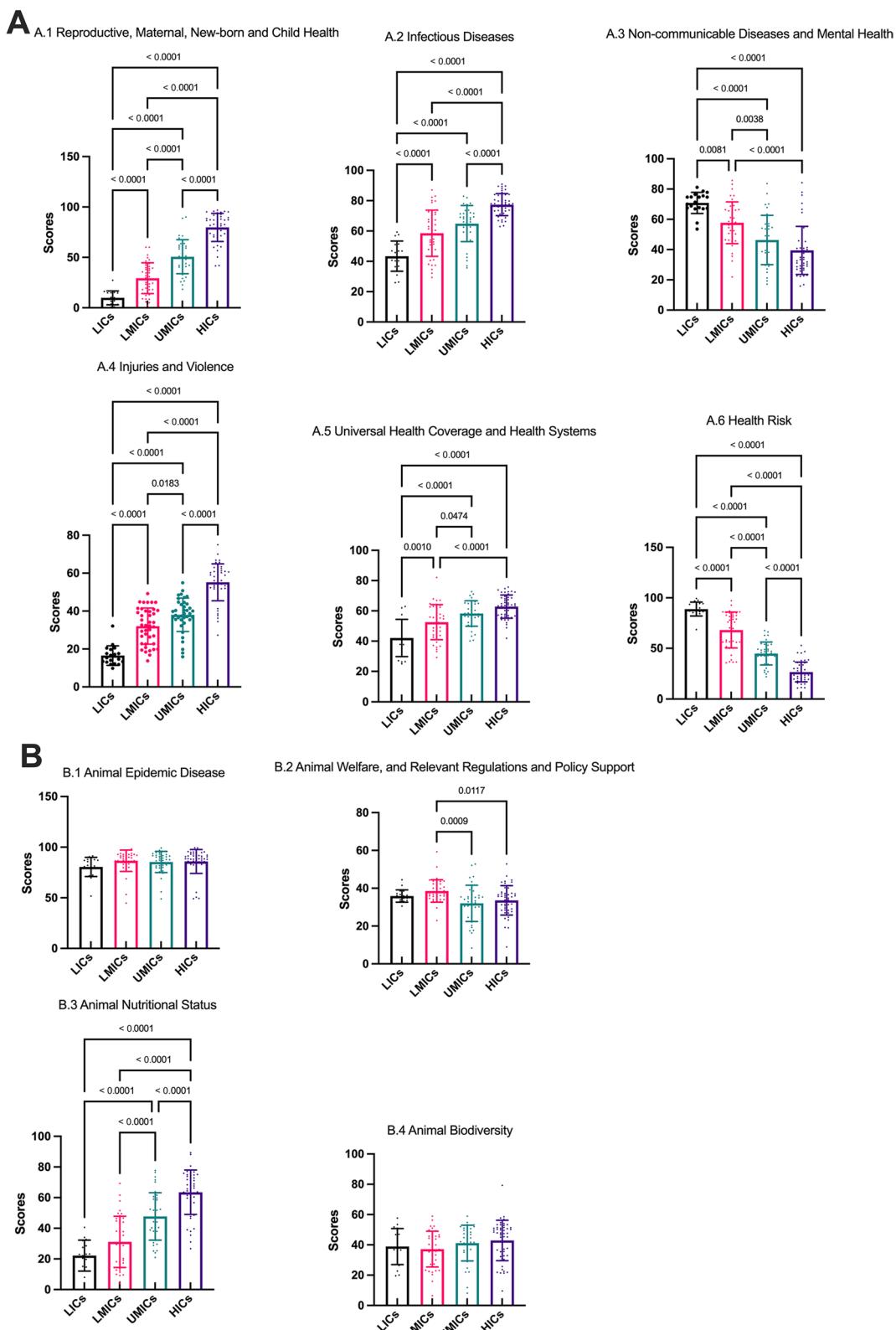
Status (Fig. 1). Since 1991, Uzbekistan has implemented several major healthcare innovations to improve the efficiency of healthcare services, including healthcare availability, governance, and financing, and to ensure equitable access to healthcare resources [28]. (3) Jordan has the best GOH-IDI performance in UMICs. Jordan's overall performance was more balanced, with five well-performing second-level, including Infectious Diseases, Non-communicable Diseases and Mental Health, Universal Health Coverage and Health Systems, Animal Biodiversity, and Animal Nutritional Status. Jordan has conducted a lot of research and practice on several components of the One Health philosophy, such as antibiotic resistance, human-animal diseases, and climate warming [29–31]. (4) Norway has the best GOH-IDI performance

in HICs. Norway performs well in most indicators, with only three that need improvement, including Non-communicable Diseases and Mental Health, Health Risk, and Land Resources (Fig. 1). Norway attaches importance to applying and promoting the One Health concept and economic development [32, 33]. Norway values cross-disciplinary development and introduces the latest technology in practice to aid in the effectiveness of interventions [33].

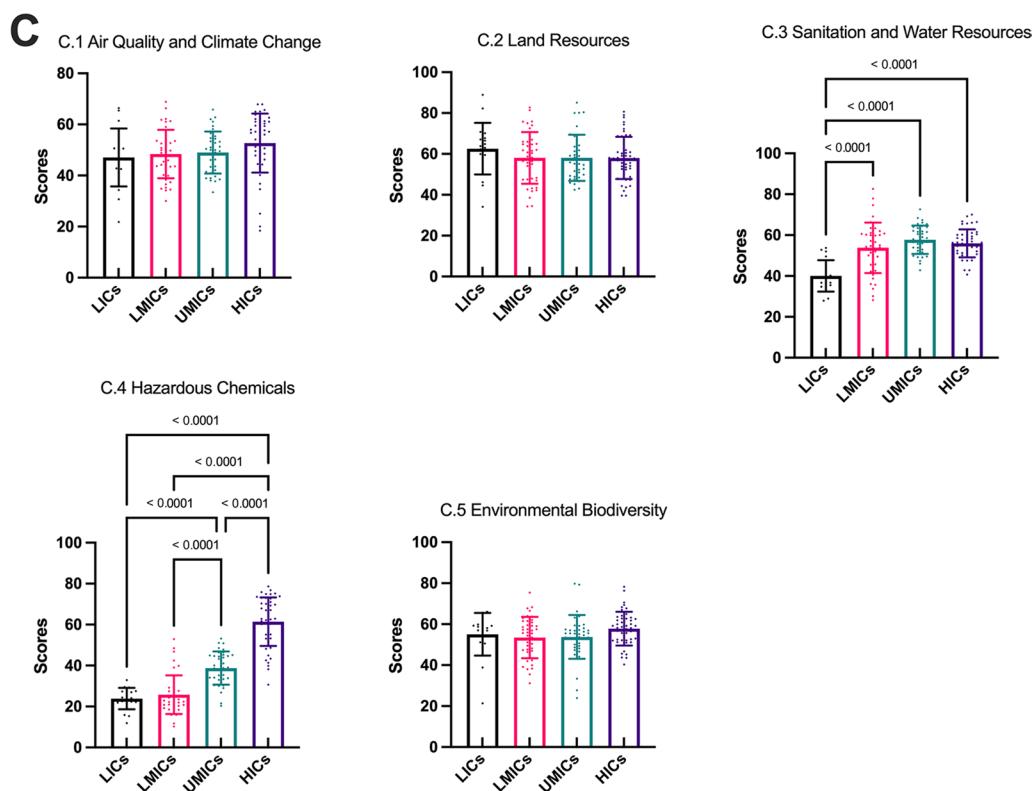
#### Policy recommendations

After analyzing and assessing the global performance of GOH-IDI and its relationship with World Bank income group, the following recommendations might be considered for policymaking in this field.

- (1) International organizations are needed to take the lead in establishing a global governance paradigm and changing the governance strategies of countries around the globe. Some indicators do not differ significantly between income groups globally (Fig. 7). These indicators are challenging to improve effectiveness through direct economic inputs, and the efforts of individual countries are limited.
- (2) Increase international and regional cooperation to achieve a win-win situation. Regional differences are apparent, with countries such as Niger, Uzbekistan, Jordan, and Norway being among the top performers in each income group (Fig. 5). The governance paradigms of these countries are valuable for their peers to learn from. In a time of globalization, complementing each other's strengths, strengthening regional multilateral cooperation, and engaging in more international cooperation will be a paradigm for improving the One Health index in the future. As countries and international organizations around the world join One Health-related initiatives and actions, the gaps between countries and regions will narrow and further improve together.
- (3) Global animal-related databases need increased diversity and data reliability. There are still relatively few animal-related databases (Table 1). Strengthening basic testing facilities and teams is necessary, and reliable data sources combined with professional analyze teams to generate realistic policy recommendations.
- (4) Strengthening the multilateral consensus and framework for action related to global climate change is necessary. Global climate change is still a big problem. The countries that emit the most greenhouse gases are not necessarily the most affected ones. Climate change has the most significant impact on tropical regions, especially in SSA.



**Fig. 7** Mean ( $SD$ ) of GOH-ID and critical indicator scores in different World Bank income groups. The different bar chart colors represent different regions. The error line represents the standard deviation. The dots represent the distribution of the data and correspond to the vertical. Detailed data are listed in Additional file 2. Descriptive analyze are listed in Additional file 3. SD standard deviation, GOH-ID/ Global One Health Intrinsic Driver Index, LICs low-income countries, LMICs lower middle-income countries, UMICs upper middle-income countries, HICs high income-countries

**Fig. 7** continued

Many of the less developed regions in the tropics suffer from extreme climate impacts while needing to fight poverty-induced malnutrition and numerous socioeconomic problems.

- (5) Combining the One Health concept to develop cross-disciplinary research and practice for efficient and universal policy development. Single discipline and departmental efforts are no longer sufficient to address the current complex international health challenges. The One Health concept guides a multi-dimensional view of problems. One Health research is directed at three main levels at this stage, including research, implementation, and governance. Areas worthy of future enhancement include drug resistance traceability, food safety, and climate change. Technical tools worthy of research include early warning systems, One Health strategic policy research, biosafety protection, One Health communication and mass behavior, big data analytics, artificial intelligence, and cloud computing technology applications.

In the process of this study, we noticed that many environmental health and animal health datasets do not have time series and lack the possibility of multidimensional

assessment. However, according to our observation, the attention to data is increasing in all world regions. In addition, there are more than 250 countries and regions in the world, and only 146 were included in this study. We will update the existing dataset and integrate a multilingual dataset in a future release.

## Conclusions

The GOH-IDI is an analyze of human health, animal health and environmental health data to assess global performance on each indicator, which helps countries understand their situation, improve global One Health action, and promote balanced development of humans, animals, plants, and ecosystems. The best performing region for GOH-IDI was North America and the worst was sub-Saharan Africa. There is a positive correlation between the GOH-IDI and country economic status, with high-income countries performing well in most indicators. From the perspective of policymakers, they need to find role models with sustainable development strategies that are like their national context to learn from. Case analysis show that some countries have outperformed countries at a similar economic level (GNI per capita) in terms of their GOH-IDI scores. These situations may be related to multiple factors, such as their social and

geographical aspects, and require more intensive investigation. For the public health field, this result can facilitate researchers' understanding of the multidimensional situation at a global level and invest more attention in scientific questions that need to be addressed urgently.

## Abbreviations

COVID-19	Coronavirus disease 2019
EAP	East Asia and Pacific
ECA	Europe and Central Asia
EPI	Environmental Performance Index
FAO	Food and Agriculture Organization
FAHP	Fuzzy Analytical Hierarchy Process
GOHI	Global One Health Index
GOH-IDI	Global One Health Intrinsic Driver Index
GBD	Global Burden of Disease
HIC	High income-country
IHME	Institute for Health Metrics and Evaluation
LAC	Latin America and the Caribbean
LIC	Low-income country
LMIC	Lower middle-income country
MENA	Middle East and North Africa
NA	North America
OIE	World Organization for Animal Health
SA	South Asia
SDGs	Sustainable Development Goals
SSA	Sub-Saharan Africa
UMIC	Upper middle-income country
WHO	World Health Organization

## Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s40249-023-01069-0>.

**Additional file 1:** Full scheme for the indicators and weights of GOH-IDI.

**Additional file 2:** GOH-IDI complete data and regional classification.

**Additional file 3:** Descriptive statistics summary.

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## Author contributions

ZG, FJ, JC, and SL conceived and designed the manuscript. ZG, FJ, JX, and LA collected and analyzed the data, and wrote the manuscript. JL, XZ, CC, JX, SX, and XZ revised the paper. Supervision: JC and SL. ZG, FJ, JC and SL finalized the manuscript. All authors read and approved the final manuscript.

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## Availability of data and materials

The full study protocol and the datasets are available, following manuscript publication, upon request from the corresponding author (Shi-Zhu Li, lisz@chinacdc.cn).

## Declarations

### Ethics approval and consent to participate

Not applicable.

## Consent for publication

Not applicable.

## Competing interests

Xiao-Nong Zhou is an Editor-in-Chief of the journal *Infectious Diseases of Poverty*. Jin Chen is a managing editor of the journal *Infectious Diseases of Poverty*. They were not involved in the peer-review or handling of the manuscript. The authors have no other competing interests to disclose.

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