Global lockdown potential impact on achieving Sustainable Development Goals

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Abstract

Coronavirus disease (COVID-19) pandemic has led to a lockdown worldwide. This restriction on human movements and activities significantly influences society and the environment. We examined the consequences of global lockdown for human movement and nitrogen dioxide (NO_2) emissions using an air pollution index and dataset and satellite image analyses. We also evaluated the immediate (during lockdown) and persistent (after lockdown) effects of lockdown on achieving the Sustainable Development Goals (SDGs). We observed a drastic decrease in human movement and NO_2 emissions and determined that many SDGs are influenced both immediately and persistently due to the global lockdown. We observed immediate negative impacts on four goals and positive impacts on five goals, especially those concerning economy issues and ecosystem conservation, respectively. The persistent effects of lockdown were predominately reversed from the immediate impacts due to economic recovery predictions. The global lockdown influences our ability to meet the SDGs, and our analysis provides powerful insights into the internationally agreed-upon SDGs both during and after the COVID-19-induced global lockdown.

Introduction

Society has drastically changed in 2020 due to the coronavirus disease (COVID-19) pandemic. COVID-19 was first observed in Wuhan, China, and it subsequently spread to every continent by April 2020 [1,2]. To reduce the spread of COVID-19, China imposed a lockdown in Wuhan City on 23 January 2020 [1]. By April 2020, people in many countries were under strict restrictions due to COVID-19 pandemic [1]. The lockdown restricted human movement, educational, political, and economic activities [3], and the consequences are expected to significantly impact both society and the environment [4–7].

Significant effects of the lockdown have already been observed on the global economy [8], air pollution [9–11], and wildlife conservation [5]. Here, multiple levels of lockdown policies [12] are considered that restrict society and behaviour. However, the effects of various global lockdown restrictions on society and the environment have not been sufficiently evaluated and synthesised, especially the resulting environmental footprint. Herein, we summarise the consequences of the global lockdown on society and the environment using air pollution and human movement indices, particularly focusing on the environmental footprint. Based on case studies and other predictions related to the COVID-19-induced global lockdown, we can evaluate and debate the impacts of the global lockdown on current and future sustainable development.

The roadmap of goal and indicator for the sustainable development of human society was established by the United Nations as the Sustainable Development Goals (SDGs) [13]. The SDGs set the agenda for 2030 to transform the world by simultaneously ensuring human well-being, economic prosperity, and environmental conservation [13]. The SDGs serve as milestones to pave the way for sustainable development for both developing and developed countries. The SDGs, comprising 17 goals and 169 targets,

address the challenges faced by humanity. The SDGs and their corresponding targets expand upon various aspects of sustainable development, including societal structure, economy, policy, and sustainable ecosystem use [13,14]. Studies have suggested that COVID-19 affects SDG achievements [4,6,7], but the studies have not evaluated the influence of the pandemic on all SDG targets. We focus on SDG achievement as a proxy to evaluate global lockdown impacts on current and future sustainable development.

We first analyse how the global lockdown affects phenomena including the national lockdown policy, human movement, and nitrogen dioxide (NO_2) emissions using an air pollution index based on database and satellite images from 'before lockdown' to 'during lockdown' (Fig. 1). Next, we present how the global lockdown due to COVID-19 in early 2020 either enabled or inhibited the achievement of the SDGs either immediately or persistently (Fig. 1). We analyse how the global lockdown influenced SDG achievements using our data and synthesised literature. We also assess the immediate (during lockdown) and persistent (after lockdown) achievements of each SDG target using a simple assessment score that has been used in a previous study [15]. Finally, we discuss the current and future influences of the global lockdown on society and the environments using the SDG scores and predict its persistent effects on SDG achievements.

Materials and methods

COVID-19 Government Response Stringency Index (GRSI)

We used data on the government responses to COVID-19, published by the Oxford COVID-19 Government Response Tracker (OxCGRT) [16]. OxCGRT collected COVID-19 GRSI daily from publicly available information for indicators, including 'school closures', 'workplace closures', 'cancel public events', 'restrictions on gatherings', 'close public transport', 'public information campaigns', 'stay at home', 'restrictions on internal movement', and 'international travel controls'. The COVID-19 GRSI is a simple additive score of these nine indicators that is based on an ordinal scale from 0 to 100. The full details can be found at https://ourworldindata.org/grapher/covid-stringency-index?time=2020-01-22.

We mapped country-level COVID-19 GRSI data from 1 March 2020 to 1 June 2020 (Fig S1).

Human migration

We used data from the global mobility report openly published by Google (https://www.google.com/covid19/mobility/) to observe daily changes in human migration. This dataset describes changes in movements from the baseline, the median value of the five weeks from 3 January 2020 to 6 February 2020 (https://support.google.com/covid19-mobility/answer/9824897?hl=en&ref_topic=9822927). The mobility changes are classified into six categories: retail and recreation, grocery and pharmacy, parks, transit stations, workplaces, and 'residential'. The data did not include any personally identifiable information, such as an individual's location, contacts, or movement. Thus, the change values were built from aggregated and anonymised datasets of users who left their location history setting on for Google services, which is off by default. We used

country-level mobility data for the six categories, collected from 15 February 2020 to 1 June 2020.

NO_2 emissions

We used satellite-based NO_2 data observed by the Sentinel-5 Precursor by the European Space Agency with a spatial resolution of 0.01° as a proxy for air pollution data [17]. The data are available from July 2018 in the Google Earth Engine environment (https://earthengine.google.com), a planetary-scale cloud computing system for satellite imagery and geospatial datasets. To obtain NO_2 data worldwide and visualise changes in NO_2 emissions in response to the lockdown policies (e.g. from March 2020 to May 2020), the monthly median of the total vertical column of NO_2 (the ratio of the NO_2 slant column density and the total air mass factor) was calculated for every 0.01° grid in April 2019 and April 2020. Subsequently, we spatially aggregated NO_2 emissions in each country and mapped the change rate ((NO_2_2020 – NO_2_2019)/NO_2_2019) for each country.

Selecting SDG targets

The 17 SDGs are said to be 'transforming our world' and are a part of the United Nations' 2030 Agenda for Sustainable Development [13]. The SDGs are associated with 169 targets, where each goal has 5 to 19 targets. We reviewed the all targets (169 targets) and selected those that were potentially influenced by the global lockdown due to the COVID-19 pandemic. Consequently, we selected a total of 73 targets of 16 goals (excluding Goal 7, affordable and clean energy, Fig. 5a). Although the goal and targets can hamper efforts to contain COVID-19

(https://www.un.org/sustainabledevelopment/energy/), we assumed that SDG 7 was not influenced by global lockdown.

Scoring procedure to evaluate the effects of the lockdown

Lockdown policies have multiple levels [12]. We included all lockdown phenomena and policies that restricted society and behaviour in the scoring. We used a simple scoring system to evaluate the global lockdown effects on the achievement of each goal, except for SDG 7, and we calculated the conflict-synergy scores following the method used by Ibisch et al. [15]. The SDG scores are based on a simple index composed of individual scores attributed to the corresponding targets where the global lockdown is relevant (Table S1).

The target score calculations were based on a simple index, where 'negative' indicates a negative influence, 'positive' indicates a positive influence, and 'neutral' indicates no influence. In addition, we scored these indices according to two timescales: 1) immediate influence and 2) persistent influence. The criteria were defined using a scientific literature review (including preprints) or without scientific literature; however, the relationship was apparent from the current discussion (Table S1). The effects of lockdown were debated, and uncertainty regarding certain effects remained [18]. Thus, we used descriptions to determine the target effects, and we did not use any specific cases.

Results

Global lockdown and its consequences

We analysed the lockdown policies, human movements, and NO_2 emissions from February 2020 to June 2020 globally. We exhibit the COVID-19 GRSI as a government policy response to COVID-19 [16] in Fig. 2. The COVID-19 GRSI scores were calculated

daily based on citizen restriction policies. We found that a higher GRSI score spread from China and its surrounding countries and increased from February 2020 to May 2020 (Fig. 2 and Fig. S1). In Asian countries, the GRSI decreased in May 2020, while other countries maintained high GRSI values during the period.

We illustrated global mobility changes to observe daily changes in human migration through Google services (Fig. 3 for the 'workplaces' and 'residential' categories). The 'Workplace' category was altered by –80% in the measured countries, while the 'residential' category increased. The other mobility categories, including 'retail and recreation', 'grocery and pharmacy', 'parks', and 'transit stations' are displayed in Fig. S2, and they also drastically decreased compared to the baseline after the global lockdown.

We spatially aggregated NO_2 emissions and calculated the change rate between the monthly median emission values for April 2019 and April 2020 ((NO2_2020 – NO2_2019) / NO2_2019) for every country, and these are mapped in Fig. 4. We found that most countries in Europe, Asia, Africa, and North and South America exhibited negative change rates between 2019 and 2020. Countries in Europe, Asia, and Africa exhibited higher change rates than those in other regions

SDG achievement scoring

Using a simple scoring method, we summarised the positive, negative, and neutral effects of the COVID-19 lockdown on SDGs achievements. We displayed the scoring of each goal (Fig. 5) for the 73 targets (Fig. 5a). We found mixed negative and positive scores for SDG achievements when considering the immediate effects of the global lockdown (Fig. 5b). We observed many negative SDG targets scores (Fig. 5b), such as

those for SDGs 2 (zero hunger), 8 (decent work and economic growth), 9 (industry, innovation, and infrastructure), and 17 (partnerships). These negatively affected SDGs predominately concerning food, economic, and industrial issues. Thus, these goals conflicted with the global lockdown. By contrast, SDGs 3 (good health and well-being), 6 (clean water and sanitation), 11 (sustainable cities and communities), 12 (responsible consumption and production), and 15 (life on land) exhibited more positive scores than the other Goals. These goals were primarily concerning human health and environmental issues, including ecosystem conservation.

When considering the persistent effects of the COVID-19 pandemic on SDG achievements, Goal 6 exhibited the same score as that of the immediate effect (Fig. 5b). The other SDGs exhibited different SDG achievements compared with their immediate responses (Figs. 5b and 5c). In particular, the scores of SDGs 11, 13 (Climate action), and 15 mostly shifted from positive to negative, which may be due to the recovery of human activities, including the economy. By contrast, SDGs 9 and 10 (reduced inequalities), 16 (peace, justice, and strong institutions), and 17 predominately changed from negative to positive, which may be due to improved governance. The detailed responses for each target are displayed in Supplementary Table S1. Several SDG targets were ambivalent concerning the global lockdown, instead of synergistic.

Discussion

We evaluated the effects of the global lockdown on society and the environment. We found drastic changes in government policies in response to COVID-19, such as increasing expenditures, reducing human movement, reducing human mobility/working style, and reducing air pollution, as evidenced by NO_2 data. The reduction in air

pollution may be a result of the reduction in the economic and transportation activities [9,18]. For example, the absence of motor vehicle traffic and suspended manufacturing during the COVID-19 pandemic in China led to a ~90% reduction in NO_2 emissions countrywide [19]. The global economy drastically slowed due to the COVID-19 pandemic [20].

These changes began in early March 2020 after COVID-19 spread globally. Such global changes in society due to a global lockdown have not been observed previously due to limited observation techniques. In this study, we examined the global lockdown consequences for human movement and ecosystems using current technologies, such as human location big data via Global Positioning System data and satellite images. Global consequences of the lockdown have been observed for other various phenomena, such as CO_2 emissions [9], air $PM_{2.5}$ concentration [21], human mobility via 'Disease Prevention Maps' by Facebook users [22], and environmental noise [23]. We have provided new consequences of the global lockdown, with results similar to those of previous reports.

The COVID-19-induced lockdown may negatively affect the achievement of the SDGs concerning food, the economy, and infrastructure (e.g. Goals 3 and 9). The global lockdown is expected to substantially influence the food supply chain [24], infrastructure, and the economy [20] due to restricted human movement, food production, and economic activities. The global lockdown may accelerate the achievements of certain SDGs, especially those focused on improving human health and conserving ecosystems. The global lockdown may reduce global climate changes due to the relative decline in air pollution (Goal 13 [9,21]), conserve sustainable cities (11), and protect life on land (15) through the lower human impact on ecosystems [5]. Consequently, human

health may improve, excluding those who contract COVID-19 (Table S1). These improvements are primarily due to restricted human movements and economic activities, which in turn reduces air pollution. Certain scholars expected reduced human mobility and activity during the global lockdown to significantly impact ecosystems [4,25], reducing the human impact on the environment allows ecosystems to recover and conserves species [4,25].

Regarding persistent effects on SDG achievements up to 2030, the SDG scores changed drastically from the immediate ones. The achievements of climate change and ecosystem protection, such as Goals 11, 13, and 15, predominately shifted from positive to negative, while those of economic issues, such as Goals 9,10, and 16, primarily exhibited a negative to positive trend. These primarily occurred because economic recovery that goes against ecosystem protection can be expected to occur after the global lockdown. Forster et al. [26] simulated the increase in global temperature after the economic recovery until 2030. Therefore, global economic recovery substantially affects the persistent achievements of the SDGs concerning ecosystem protections and reducing climate change. There were conflicting phenomena among goals aimed at protecting biodiversity and promoting economic development [15,27]. Therefore, a comprehensive debate is necessary to consider the achievements of SDGs after global lockdown concerning economic recovery and ecosystem management.

There is growing scientific evidence on how to achieve SDGs [15,28–30], and the impacts of the global lockdown have been well evaluated using the current global policy framework. Moreover, major global lockdown policies and the subsequent economic recovery, such as the cohesion policy of developed countries may not consider the

future SDG achievements for 2030. Therefore, policies concerning SDGs should be considered while factoring in the global lockdown and subsequent economic recovery.

This study and perspective have certain limitations. Our simple score analysis for SDG achievements represents findings in the literature on how the global lockdown affects the SDGs. Although we carefully considered the scores, certain scores may have been overlooked or underestimated. In addition, we should assume that new evidence of the global lockdown effects on SDGs will be published in the future. Considering these limitations, the scoring estimates have various uncertainties. Therefore, we recommend studying the reality of SDGs achievement in the future by directly measuring the SDGs, human movement, and air pollution. We scored the achievements of SDGs at the global scale by limiting the data; however, developing countries are more greatly influenced by the global lockdown due to their limited governmental budgets [31]. Therefore, we encourage SDG achievements to be assessed at the country or regional level.

In conclusion, we have illustrated the changes in society and the environment, and SDG achievements due to the immediate and persistent effects of the global lockdown due to the COVID-19 pandemic. Global lockdown significantly impacted society and the environment. The global lockdown greatly impacted the immediate achievements of most SDGs, with primarily negative and positive effects on economic and environmental issues, respectively. In addition, we found the persistent effects of achievements for most of the goals. We are at a critical turning point for the future of human society and the Earth with regard. The SDG achievement analysis provides powerful evidences from the SDG perspective [30]. In addition, the SDGs represent a leap forward compared to the Millennium Development Goals [32]. Humanity is currently facing the COVID-19 pandemic; however, to achieve a sustainable society, shared

principles and legislation among nations must be developed. The political choices made during and after the COVID-19 pandemic can assist the development of a sustainable society by 2030.

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Author contributions

H.D., T.O., and N.T. designed the study; N.T. collected the spatial data; N.T. and T.O. analysed the data; H.D., T.O., and N.T. interpreted the results; and H.D., T.O., and N.T. wrote the manuscript.

Competing financial interests

The authors declare no competing financial or non-financial interests.

Materials & Correspondence

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Figure legends

Figure 1 Conceptual illustration of the COVID-19 pandemic effect on SDG achievements through global lockdown consequences of societal changes. The COVID-19 GRSI is used as the lockdown degree index for each country on 15 June 2020. Illustrations are adopted from Irasutoya (https://www.irasutoya.com), except for SDG icons and the figure. SDG icons are adopted from https://www.globalgoals.org/resources.

Figure 2 Country-level COVID-19 GRSI for (a) 1 March 2020 and (b) 1 June 2020. The index displays the degree of lockdown due to the COVID-19 pandemic.

Figure 3 Mobility changes in the workplace and residential places from the baseline (the median value of the five weeks from 3 Jan 2020 to 6 February 2020) from 1 March 2020 to 1 June 2020.

Figure 4 Change rate of country-level monthly median NO_2 between April 2019 and April 2020.

Figure 5 Scoring of global lockdown effects on SDG targets. (a) Evaluated targets for each goal. Scores of the (b) immediate and (c) persistent effects of global lockdown on each goal.

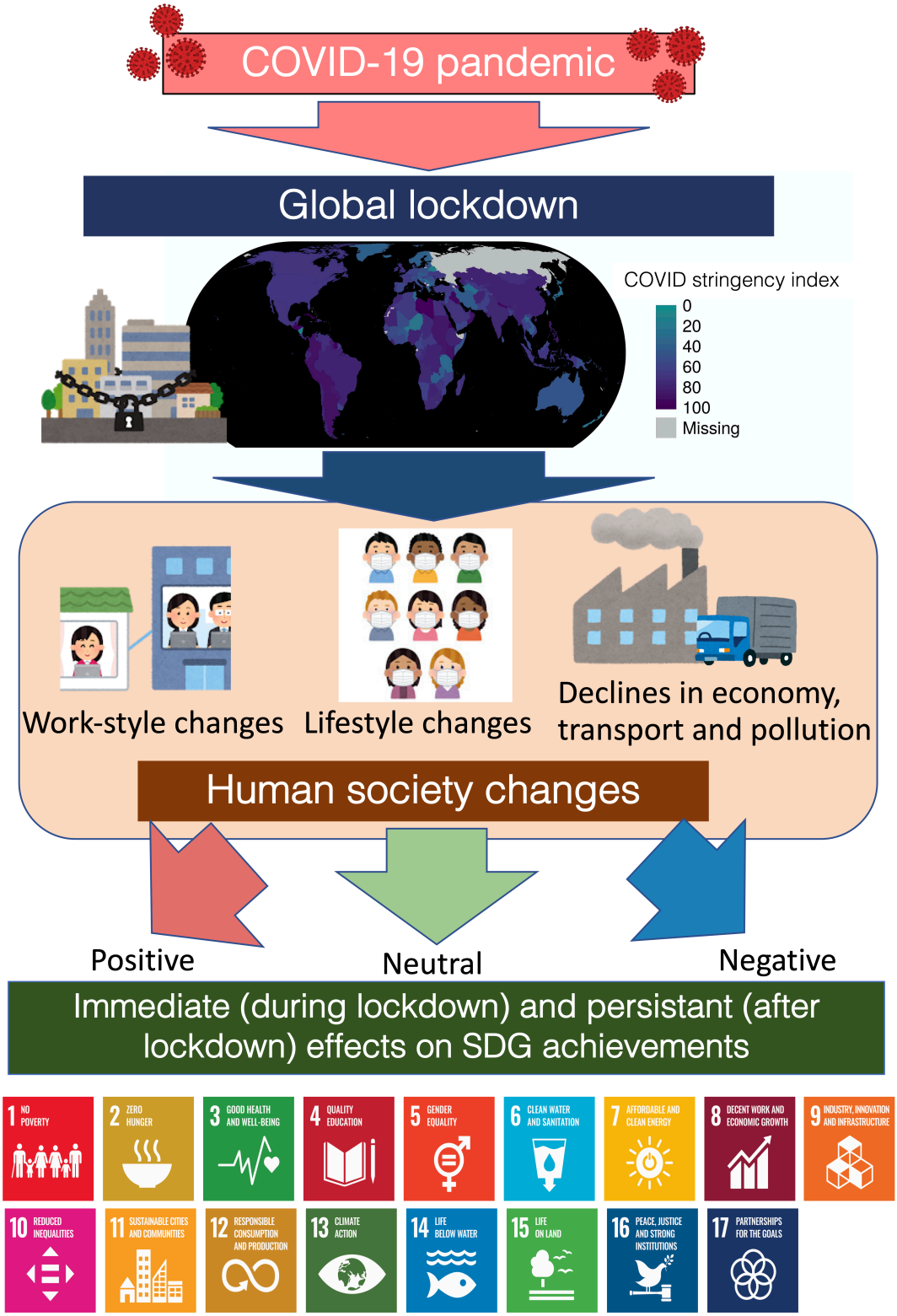
COVID-19 pandemic
Global lockdown
COVID stringency index
0
20
40
60
80
100
Missing
Work-style changes
Lifestyle changes
Declines in economy, transport and pollution
Human society changes
Positive
Neutral
Negative
Immediate (during lockdown) and persistant (after lockdown) effects on SDG achievements
1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS

Figure 1

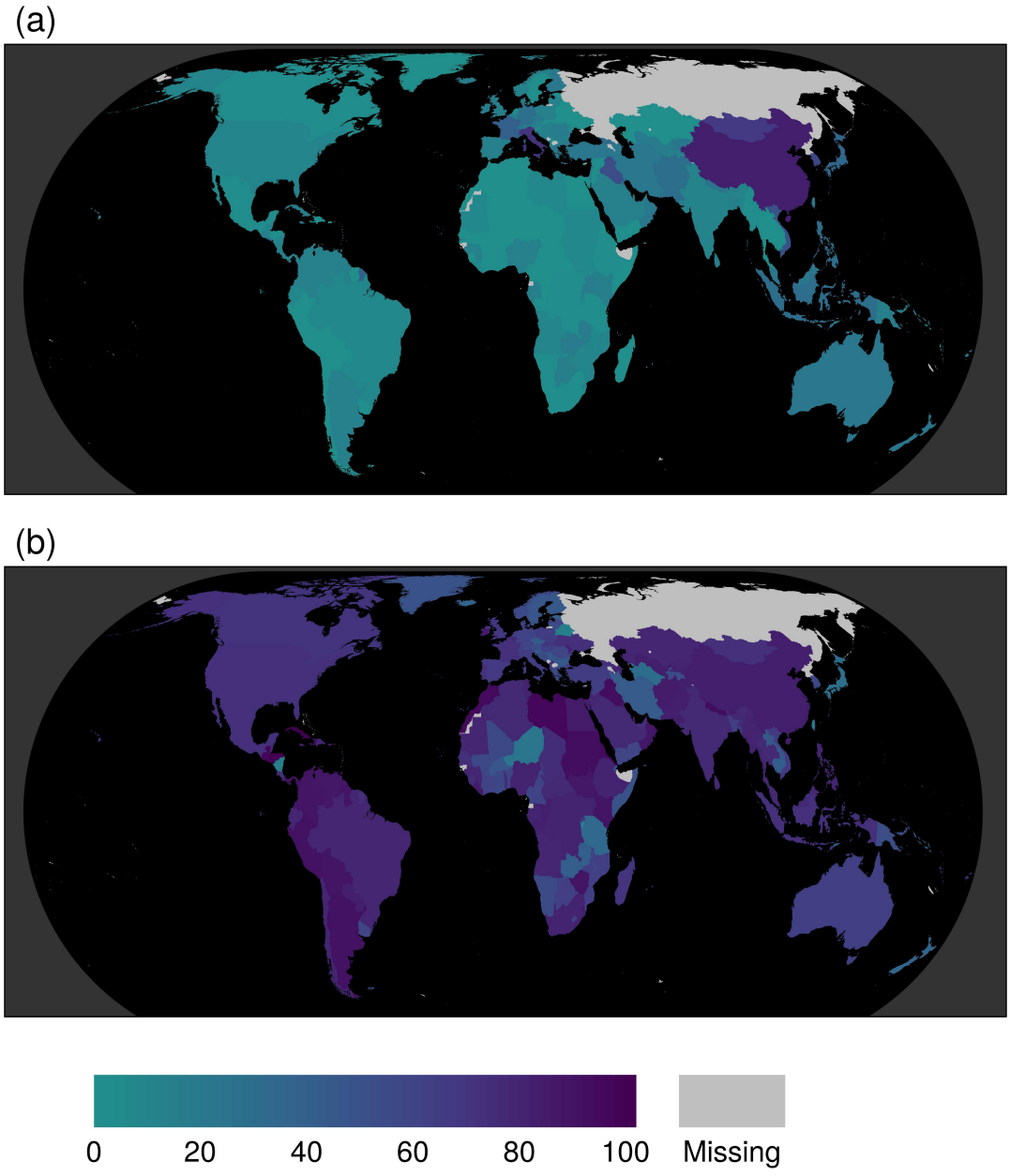

Figure 2

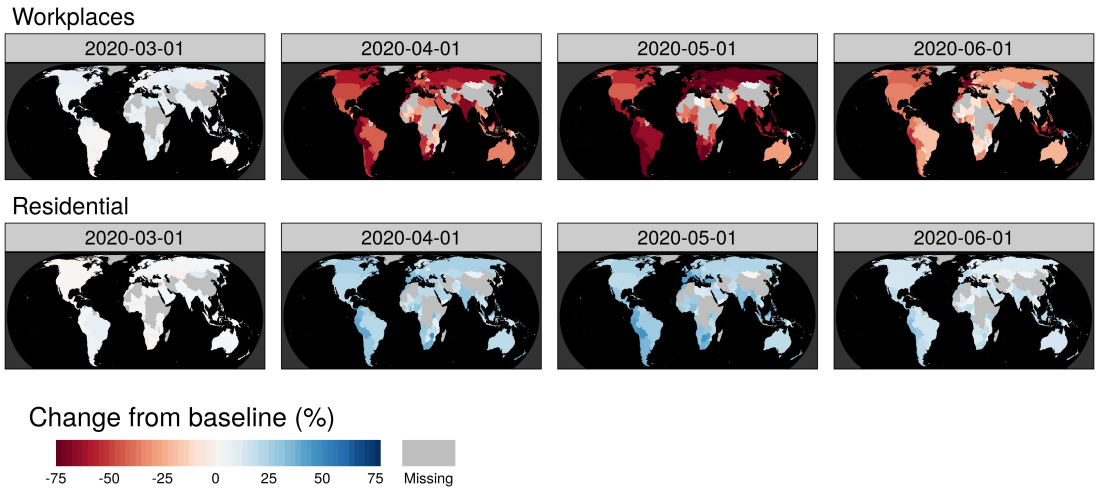
Workplaces
2020-03-01
2020-04-01
2020-05-01
2020-06-01
Residential
2020-03-01
2020-04-01
2020-05-01
2020-06-01
Change from baseline (%)
-75
-50
-25
0
25
50
75
Missing

Figure 3

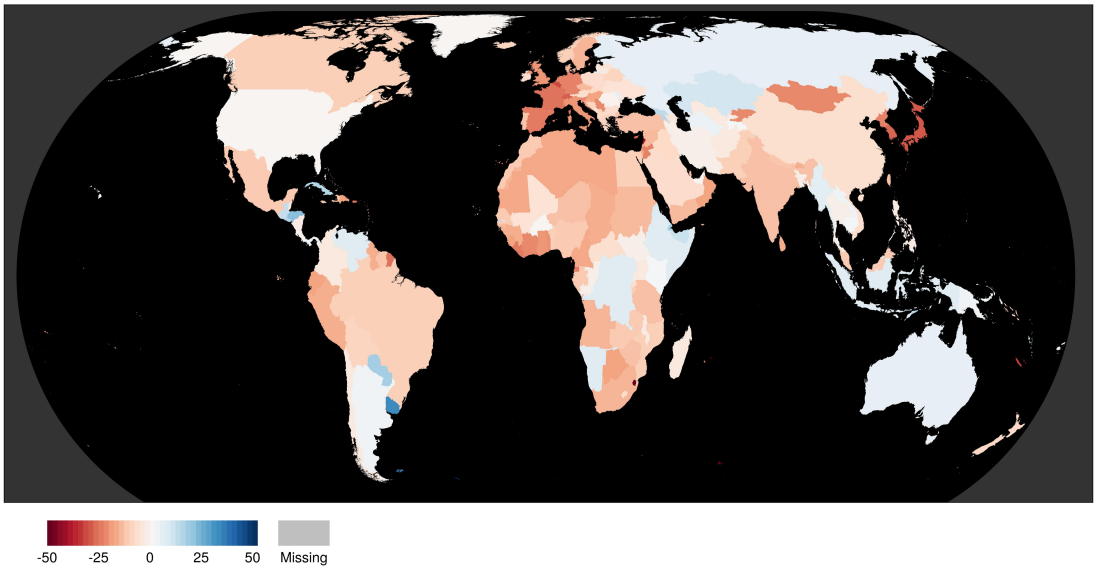

Figure 4

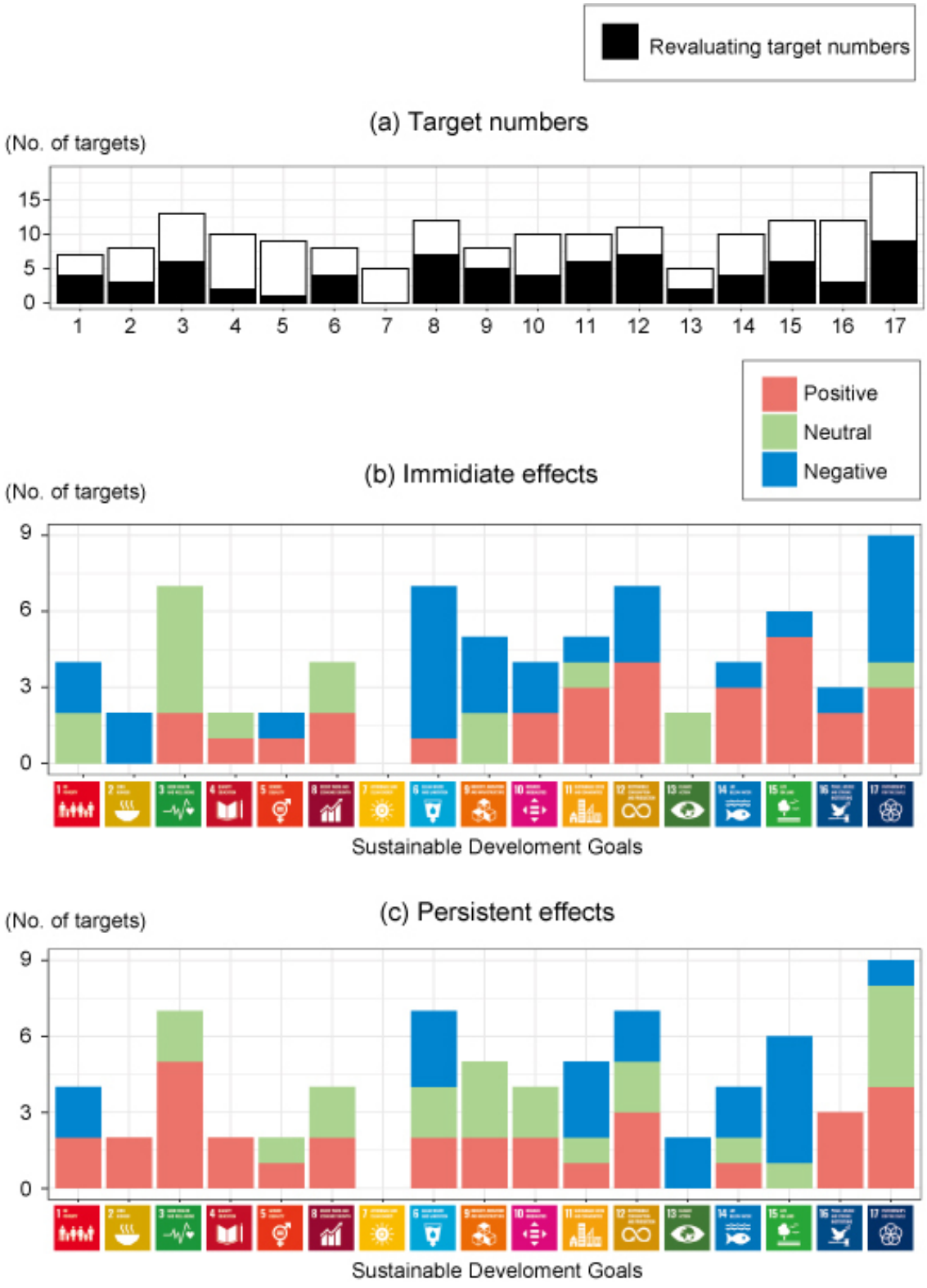
Revaluating target numbers
(a) Target numbers
(No. of targets)
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Positive
Neutral
Negative
(b) Immidiate effects
(No. of targets)
9
6
3
0
Sustainable Develoment Goals
(c) Persistent effects
(No. of targets)
9
6
3
0
Sustainable Develoment Goals

Figure 5