WFP World Food Programme

COVID-19 and climate: Possible geographical and temporal patterns[1]

A review of climate scenarios for COVID-19 spread

Summary

- Weather factors play a role in the spread of influenza and there is an interest in investigating if weather factors play a role in the spread of Covid-19. If this were the case, valuable information on future temporal and geographical scenarios of Covid-19 expansion could be obtained.
- Very recent (and not yet peer-reviewed) research points to some influence of weather factors in the transmissibility of SARS-Cov2, specifically that colder temperatures and lower humidity may favour transmission. While a number of studies show a significant correlation between temperature, humidity and disease transmission, the two factors explain only a small fraction of the overall variation in transmission rates.
- A model was identified that relates the reproductive number of SARS-Cov-2 with temperature and humidity. Using global data on these two variables, we prepared maps showing the broad patterns of potential SARS-CoV-2 transmission and how this might change during the calendar year. We wanted to know whether there are countries in areas of WFP intervention where scenarios of potentially enhanced transmission might develop, in particular those with high levels of poverty, food insecurity and high exposure to the economic impacts of Covid-19.
- It needs to be stressed that the results shown here are **not predictive** of Covid-19 spread in any way, shape or form. Having been derived from long-term averages of weather variables, they need to be viewed as maps of potential environmental suitability rather than maps of specific SARS-Cov-2 reproductive number.
- Areas of suitable climate conditions for transmission during the month of March broadly replicate the major areas of current Covid-19 spread along a belt between 30 to 50 N. In August, suitability decreases in the northern hemisphere and increases in southern hemisphere countries.
- Where decreases in climate suitability take place, this **does not imply** that numbers of infected people and fatalities will automatically decrease by virtue of weather alone. These decreases can only come about by pursuing public health measures, as the transmission of SARS-Cov-2 remains significant. At most, this may indicate that these measures may have a greater chance of producing improved results before suitability increases again towards the end of the year.

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- For WFP, the major potential area of concern is Southern Africa: environmental conditions will become more favourable for SARS-Cov-2 transmission and there are a number of adverse factors that may come into play – poverty, presence of HIV-AIDS, economic crisis. The Middle East is another source of concern, given instability in many countries of the region and the possible existence of suitable conditions for SARS-Cov-2 spread throughout the year.

Background

Right from the beginning of the spread of the SARS-Cov-2 virus and the associated Covid-19 disease, there was an interest in investigating whether weather factors might play a role in the speed of the disease transmission. If this were the case, valuable information on future temporal and geographical scenarios of Covid-19 expansion could be obtained.

There are precedents for some climatic influence on viral transmission. The influenza virus shows significant seasonal fluctuation in temperate regions of the world but reduced seasonality in tropical areas [9]. Specifically, high temperature and high humidity significantly reduce the transmission of influenza; colder temperatures enhance the spread of respiratory aerosol and droplets; warmer temperatures favour the breakdown of the lipid cover of corona viruses; cold and dry weather can also weaken the hosts' immunity and make them more susceptible to the virus [9].

These mechanisms may also reduce the viability of SARS-Cov-2 but it is a bit too early to know for certain whether it is similarly affected. A number of papers considering this topic have recently appeared, mostly published in https://www.medrxiv.org/ or https://papers.ssrn.com/, none of which has yet been peer reviewed (see last section References).

These papers concentrate on the role of air temperature and of atmospheric humidity whether combined or in isolation. The simpler approaches ([6], [7]) observe similarities between geographical spread of Covid-19 and temperature or humidity patterns; the temperature and humidity conditions of geographical areas with high incidence of cases are used to define broad intervals of the two variables deemed favourable for SARS-Cov-2 transmission. The more complex approaches ([1], [2], [5]) attempt to model the contribution of temperature and/or atmospheric humidity to the spread of Covid-19 or the SARS-Cov-2 reproductive number (a measure of infectiousness). Most papers also highlight the fact that even where an influence of weather is identified, this is usually weak and will not by itself be able to cause a significant reduction in the transmission of SARS-CoV-2 and the spread of Covid-19.

A major difficulty is of course that since the early stages of the spread of Covid-19, governments around the world have put in place a range of public health measures to try and contain the spread of the virus. Being variable in scope and degree of enforcement, these introduce additional uncertainty in the assessment of the influence of weather on Covid-19 propagation.

Review of Published Studies

Most papers published on the relationship between weather variables and Covid-19 spread, focus on the role of air temperature and of atmospheric humidity whether combined or in isolation. The simpler, earlier approaches ([6], [7]) observe similarities between geographical spread of Covid-19 and temperature or humidity patterns; the temperature and humidity conditions of geographical areas with high incidence of cases are used to define broad intervals of the two variables deemed favourable for SARS-Cov-2 transmission.

For instance, Bukhari and Jameel [6] proposed a temperature range of 3C to 17C and absolute humidity of 4-9g/m3 that would contain 90% of the transmission cases at the time. This was a very tentative analysis and the authors state "*It is highly plausible that we may see a rise in the number of cases in regions with temperature >20C in the next few weeks, and similar to SARS-CoV the temperature at which slow-*

down of the transmission might happen (if any) may only be at above 25C". They propose a criterion of absolute humidity of 4-9g/m3 – reliance only on this bracket can actually accommodate a wide range of air temperatures and relative humidity (cf Fig 5 in the paper) and some use is made of it in the results presented below.

The more complex approaches ([1], [2], [5]) attempt to model the contribution of temperature and/or atmospheric humidity to the spread of Covid-19 or the SARS-Cov-2 reproductive number (a measure of infectiousness). They point to the same broad conclusion that lower temperatures and humidity may favour SAS-CoV-2 transmission. These studies while uncovering a significant correlation between temperature, humidity and disease transmission, also show that "the two factors explain only a small fraction of the overall variation in transmission rates" [10].

> The **basic reproductive number** R0 of an infection is the expected number of cases directly generated by one case in a population where all individuals are susceptible to infection. Higher values of R0 imply that infections spreads faster and are harder to control. Public health measures (lockdowns) and behaviour (enhanced hygiene) aim at reducing R0. If R0 is below 1, the disease will progressively die out.

An interesting paper is the one by Wang et al [1] which derived SARS-Cov-2 reproductive number (R_0) and modelled it as a function of air temperature and relative humidity, using data for 100 Chinese cities. They used data on SARS-Cov-2 propagation only until the beginning of the Chinese government intervention and subsequent restrictions on movement and lockdown measures (Jan 24). Hence this may be viewed as an estimate of the virus "natural" reproductive number in the absence of public health measures. The range of temperatures under consideration was about -21C to +22C and relative humidity from about 45% to 100%. The linear model they derived shows the R_0 decreasing with increasing temperature and increasing relative humidity, with the effect of temperature being slightly stronger. However, the meteorological variables even if significant explain only a small proportion of the variability in the reproductive number.

Potential Geographical Patterns and Temporal Dynamics of Covid-19

In this analysis, we applied the Wang et al model of R_0, using global long-term monthly averages of air temperature and relative humidity [*Essential climate variables for assessment of climate variability from 1979 to present*, https://cds.climate.copernicus.eu/cdsapp#!/dataset/ecv-for-climate-change] as inputs. The objective is to map at global scale the outputs of this model, verify if results are in broad agreement with current Covid-19 spread, and to see how changes in temperature and humidity along the calendar year change the geographical patterns of infectiousness. In particular, we wanted to check if there are countries in areas of WFP intervention where the model points to potentially enhanced transmission, especially if these are countries with high levels of poverty and food insecurity, and existing vulnerability to the economic impacts of Covid-19.

It needs to be stressed that the maps shown in this section are **not predictive** in any way, shape or form. They are a global extrapolation based on a limited number of Chinese cities over a limited amount of time. They simply serve to highlight possible broad patterns and changes in the environmental suitability for SARS-Cov-2 propagation. We refer to the modelled R_0 as climate-R_0 to emphasise this difference.

Results are shown for March and August. Areas of very low population density (Siberia, northern Canada and Greenland) have been masked so as not to visually dominate the map and to circumscribe patterns of SARS-Cov-2 transmission to areas with significant population density. Areas with an absolute humidity bracket of 3-12 g/m^3 are also shown in the maps: papers that included this variable in their analysis ([2],[3],[6]), signalled similar ranges as the most favourable for Covid-19 spread.

The first two maps (Fig 1) show the global patterns of climate-R_0 for March (current month) and August (southern hemisphere winter). In the map for March, we see clearly the areas with high climate-R_0

across a belt from 30 to 50N, North America to Western Europe across the Middle East and into China – in spite of its simplicity and having been based only on data from China, the model is able to replicate major areas of current Covid-19 spread.

In August, we see the overturning of favourable conditions across the Sahel (the first quarter of a year is also a prime period for the spread of other diseases such as meningitis for which climate plays a role). There is also a generalized decrease in India and SE Asia, Western Europe and North America. In contrast, Southern Africa and South America register increases. Most of the Middle East remains the same – in the model, the very low relative humidity must be compensating for high temperatures. At this time of the year, this region mostly registers temperatures and humidity outside the range for which the model was tested so results for this region should be taken carefully.

Note that where decreases in climate-R_0 take place, this **does not** imply that numbers of infected population and fatalities will automatically decrease by virtue of weather alone. These decreases can only come about by pursuing public health measures. At most, this may indicate that these measures may have a greater chance of producing improved results.

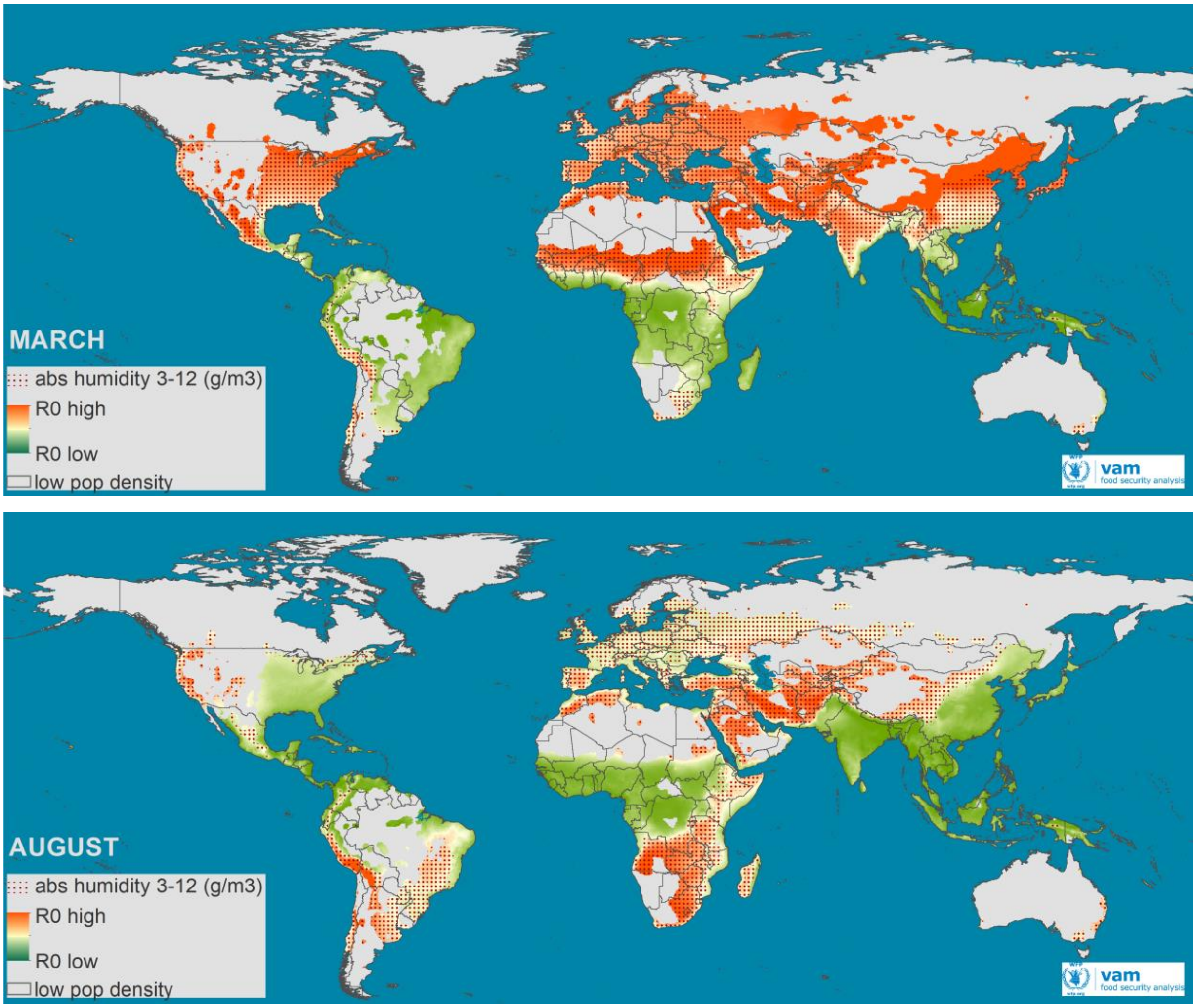

Fig 1: Map of climate-R_0 at global scale for the month of March (top) and August (bottom). Dots show areas with humidity bracket favouring Covid-19 spread. R0low is 1, R0high is 2.5

Next we investigated the seasonality patterns of climate-R_0. The yearly maximum of R_0 (Fig 2) shows that most of the globe is likely to reach high R_0 values at some stage. The exception are perennially warm and moist areas such as Central Africa (north and central DRC, Congo, Gabon) and the Indo-Pacific region (Malaysia-Indonesia-Philippines-PNG).

The month when the climate-R_0 maximum is reached is also shown in Fig 2. For SE Asia, China and western half of the USA, peak R_0 occurs in December-January; for Western Europe this takes place in February and March for the Iberian Peninsula. Iran and Afghanistan register the peak in October-November. For Southern Africa and South America, the peak is mostly in August-September. For all regions, the time of the minimum is broadly the opposite in calendar terms (six months before-after), so areas with a maximum in July-September have a minimum in January-March.

So, taken globally, there are two key periods with potentially heightened Covid-19 transmission: January-March across the northern hemisphere: January for China, North America and western Sahel, February-March for Western Europe, eastern Sahel and the Indian subcontinent. July-September for the southern hemisphere.

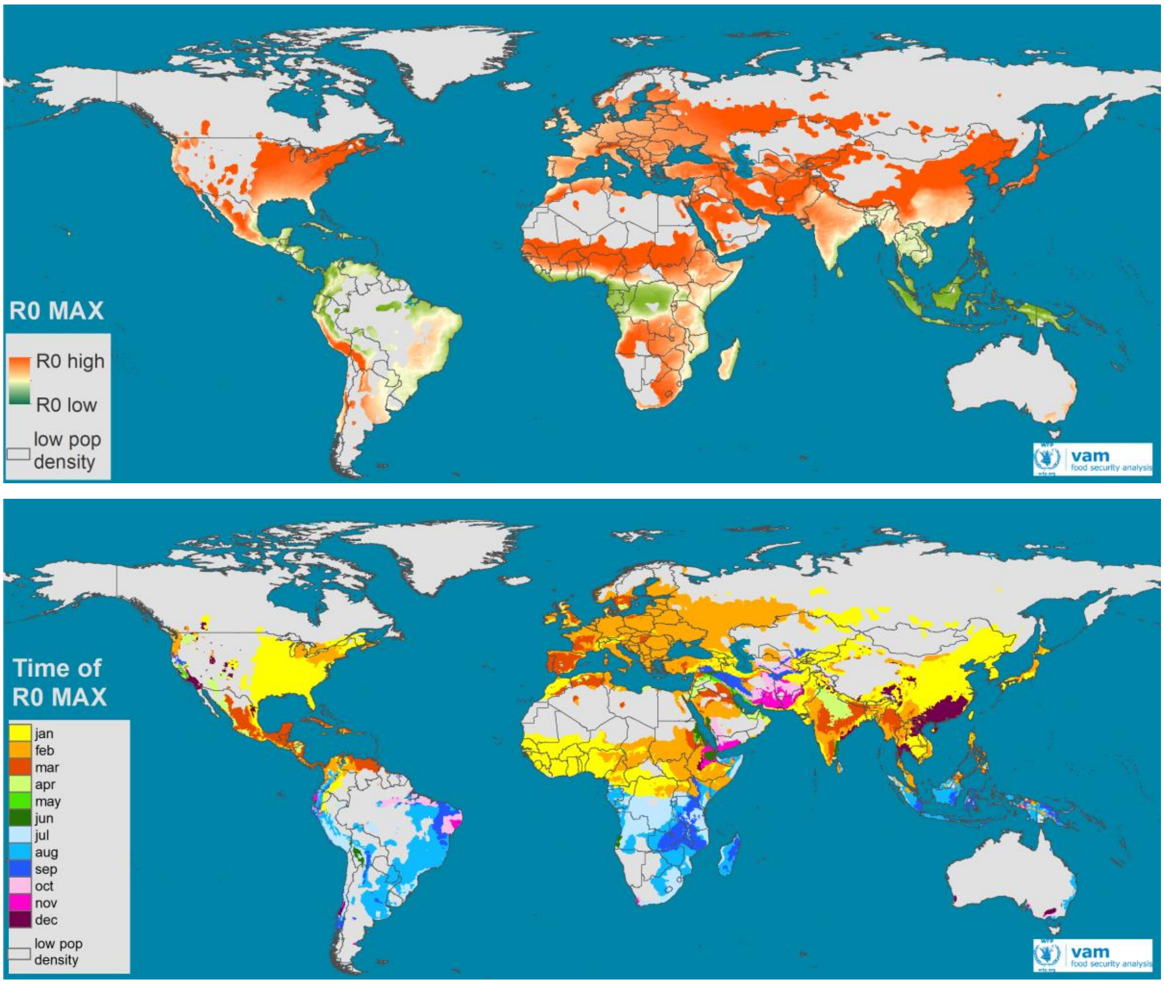

Fig 2: Map of annual maximum climate-R_0 (top R_0low is 1, R_0high is 2.5) and month of the year when that maximum is reached (bottom)

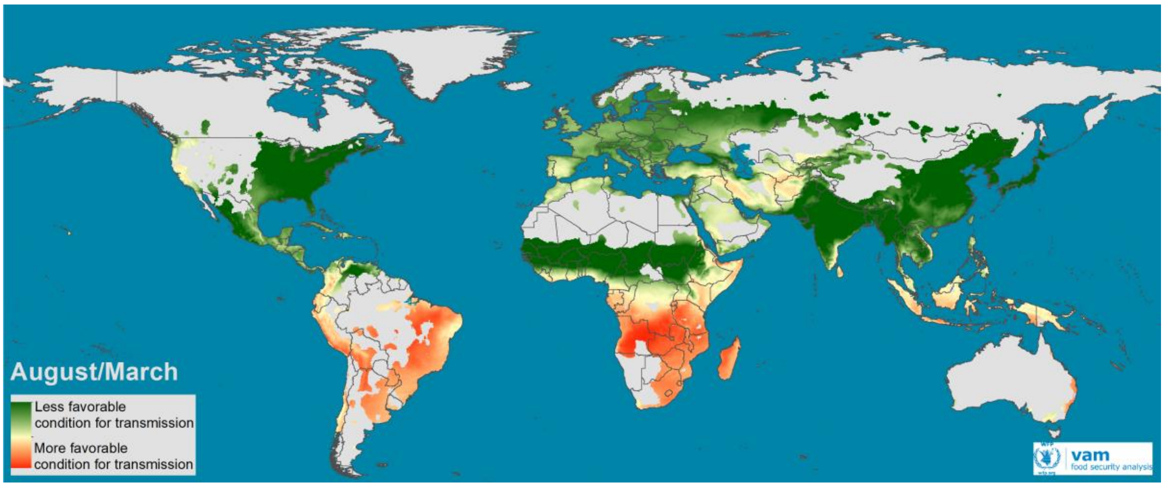

Fig 3: Map showing changes in climate-R0 from March to August – decreasing in green, increasing in orange

Mapping the sign and intensity of the change from March to August makes clear the areas where decreases in climate-related R_0 may take place – eastern USA, Sahel, India, SE Asia and China. Western Europe will see a less marked decrease over this time period. The Middle East region and Central Asia may not see any significant change, though derived values for August use inputs with values outside the range of values used in the model. Note that, in spite of these decreases, infectiousness will not be reversed (again public health measures are critical).

In contrast, increases will take place in Southern Africa and South America from March to August, pointing to the need for timely implementation of public health measures.

Areas of Concern

The broad dynamics of SARS-Cov-2 climate-R_0 offer only a rough overview of where the prevalent climate might be more favourable to SARS-Cov-2 transmission. In areas that are currently most severely affected, a decrease in R_0 due to changes in the weather (i.e. increase of temperature and humidity as Spring advances and summer arrives) will not lead to a decline in the spread of Covid-19 without maintenance of significant public health interventions. *The weather over coming months is likely to bring modest reductions in the spread of Covid-19 but it is the nature and intensity of public health interventions which will be the main driver of the total numbers of infected*. These reductions may be less significant in Europe compared with the USA or Asia. All of these regions may have to deal with enhanced transmission towards late 2020 – early 2021.

A different picture emerges for the southern hemisphere. Current number of infected people are fairly low but this coincides with the period of lowest climate-related transmission potential. In three months, this should reach its seasonal maximum. Where there are already public health measures being taken, these might need to be strengthened and initiated where they are still absent.

Modelled low transmission conditions are just indications from broad environmental patterns – the analysis used long-term averages and actual conditions may enhance or intensify transmission. There are plenty of micro-climatic environments that may favour transmission even when/where broad-scale conditions are unfavourable: crowded and unsanitary living conditions of the urban poor (or cool and dry air-conditioned malls and hotels at the other end of the income scale) may offer suitable environments for SARS-Cov-2 spread.

For WFP, the principal potential area of concern is Southern Africa – the region is advancing towards winter and temperatures and humidity can get fairly low, particularly in inland areas, raising transmission potential. A number of adverse factors may come into play: high levels of poverty with limited ability to deal with lockdown-type public health interventions and respective loss of income, serious macro-economic crisis and very poor crop production perspectives (Zimbabwe), presence of immune-compromised populations due to HIV-AIDS. These factors may potentiate the increased transmission conditions brought by weather patterns into a serious public health problem. Another potential area is the Middle East, where economic crisis and large-scale conflict can hamper public health measures while amplifying their potential impacts.

Countries at risk in the short term (June-September) and tentative aggravating factors:

Countries	Context / Aggravating Factors	Economic Drivers
Zimbabwe **Major Economic Impact Country (*)**	Poverty, HIV, Poor Crop production, Macro-economic crisis, poor infra-structure and public services	Macro-economic crisis: hyper-inflation, low foreign currency reserve, dependent on export of primary commodities, dependent on food imports. Likely border closures to impact on migrant labour.
Angola **Major Economic Impact Country (*)**	Poverty, Economic crisis (low oil price?), HIV	Dependent on export of primary commodities, low foreign exchange reserve
Zambia **Major Economic Impact Country (*)**	Poverty, HIV	Dependent on export of primary commodities, high public debt, low foreign exchange reserve
DRC (SE only) **Major Economic Impact Country (*)**	Poverty, poor infra-structure and public services	Dependent on export of primary commodities
Mozambique **Major Economic Impact Country (*)**	Poverty, HIV, Drought in southern areas. Lower potential transmission than elsewhere	Dependent on exports of primary commodities, high public debt
Malawi	Poverty, HIV	Largely dependent on export of labour and remittances
Madagascar	Poverty, Drought in southern areas. Lower potential transmission than elsewhere	
Lesotho	Poverty, HIV	
eSwatini	Poverty, HIV	
South Africa	HIV. Wealthier, though with high poverty rates; better infrastructure, early adoption of strong public health measures	Likely border closures to impact on migrant labour of neighbouring countries.
Namibia	HIV, Budget constraints. But relatively wealthier, better infrastructure, sparsely populated	
Botswana	HIV. But relatively wealthier, better infrastructure, sparsely populated	

(*) https://docs.wfp.org/api/documents/WFP-0000114040/download/

Countries	Context / Aggravating Factors	Economic Drivers
Syria **Major Economic Impact Country (*)**	Large scale conflict	Macro-economic crisis: inflation, weak exchange rate
Lebanon **Major Economic Impact Country (*)**		Economic crisis
Jordan		

Iraq **Major Economic Impact Country (*)**	Civil unrest	Dependent on exports of primary commodities
Iran **Major Economic Impact Country (*)**	Economic crisis	Dependent on exports of primary commodities
Kyrgyzstan		Dependent on remittances
Tadjikistan **Major Economic Impact Country (*)**		Dependent on exports of primary commodities and remittances
Afghanistan **Major Economic Impact Country (*)**	Conflict	Dependent on food imports

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