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Examining Trends in the Food–Energy–Water Security Nexus and Its Relationships with Human Development, Population Growth, and Conflict

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Abstract: Abundant and accessible food, energy, and water are essential to the functioning of human societies and individual health and happiness. However, growing populations, intensifying climate change, and violent instability undermine resource security. We used data from the recently updated Pardee RAND Food–Energy–Water (FEW) Index and the INFORM risk model to assess global and regional trends in resource security and relationships with the Human Development Index (HDI), internal conflict risk, and population growth. Our analysis finds that resource security has modestly improved with an average global FEW Index improvement of 2.61%, but this figure masks significant regional disparities, with several countries in Sub-Saharan Africa and South Asia regressing in terms of food and water security. We observe continued high correlations between HDI and the FEW Index (0.8664) and also find the FEW Index to be highly correlated with national income per capita (0.6547). We also find that at a global level, there is a significant negative association between trends in the FEW Index and population growth (−0.4724) during the study period, suggesting that a growing proportion of the global population is experiencing resource insecurity. Finally, our analysis suggests that several resource-insecure countries are also conflict-prone and these nations tended to do worse over the study period than similarly resource-insecure states that were internally stable.

Keywords: food security; energy security; water security; conflict; food; energy; water nexus; human development

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1. Introduction

Human wellbeing is fundamentally dependent on secure access to and sufficient availability of three basic resources: food, energy, and water. Access to and availability of these resources contribute to improvements in human health, productivity, and happiness, which in turn are associated with macro-level outcomes such as economic growth and educational attainment [1]. These relationships highlight the importance of food, energy, and water resource security to helping countries and regions reach attainment of the U.N. Sustainable Development Goals (SDGs) [2].

Food, energy, and water insecurity have long been considered key challenges in the process of human development, but until the recent past, they were distinct issues that were to be tackled independently of one another [3]. There is a growing realization, however, that food, energy, and water systems are interconnected. In 2011, the Bonn Nexus Conference coined the phrase 'water, energy, and food security nexus' to describe the synergy between these systems [4]; this descriptor has percolated across the world, though it is also commonly organized as 'food, energy, and water security', commonly abbreviated as FEW. The nexus approach enables policymakers to identify synergies and tradeoffs in the management of FEW resources and to develop integrated policies that improve resource security holistically [5]. A siloed approach towards resource management could also be detrimental to progress on global development for achieving the SDGs [6].

The FEW framework is also particularly salient as the world grapples with demographic and climate changes. The lack of one resource typically disturbs access and availability of other resources in the framework as well [2]. For instance, water is an essential requirement for agriculture in the form of irrigation and it is also a key source of energy as hydropower is a significant power source in several parts of the globe. However, in many regions, intensifying climate change is threatening water security and causing tensions between agricultural and energy production applications [7].

Besides the idea of a nexus between different kinds of resource security, there is also an emerging concept of a sustainability–peace nexus as natural resources have been found to play a role in creating conditions for conflict [8]. The core importance of peace for development outcomes is highlighted by its centrality to the Sustainable Development Goals [9]. However, growing global populations have the potential to undermine this peace by stressing resource security, especially in areas where food, water and energy resources are already limited [10]. The global population is projected to increase significantly in the upcoming decades and much of this growth is expected to occur in low-income countries that are in many cases already struggling with resource security [11].

This can lead to intense competition for resources, and it has been previously theorized that the growing rarity of essential resources such as water may spark armed hostilities as different states and groups seek to control them [12]. This can spark a vicious cycle as natural and anthropogenic causes reduce the availability of resources, causing conflicts, which in turn further reduce resource security due to the effects of war such as destroyed infrastructure. Rapid population growth also affects resource security in the absence of conflict by undermining economic growth and reducing the revenues available to improve living standards and provide energy, food, and water. In this manner, rapid population growth has been referred to as a challenge-multiplier [13]. Therefore, the confluence of growing populations, urbanization, economic development, and climate change poses a key challenge to the provision of FEW resources and advances in development outcomes [14].

The Pardee RAND Food–Energy–Water (FEW) Index uniquely describes aspects of resource security at the household level, which provides a level of detail relevant for human development [1]. The index individually measures food security, energy security, and water security in terms of up to three dimensions: access, availability, and adaptive capacity. The three individual resource security ratings are then combined to calculate an overall FEW Index.

In 2024, RAND released an updated version of the FEW Index that incorporated data released since the first publication of the Index [15]. These updated data provide an opportunity to examine recent trends in FEW security globally and how trends in resource security compare to other global trends and conditions affecting human development.

Our study makes two novel contributions. First, it features the first analysis of trends in resource security using time-series data. Although the literature contains several papers that assess resource security at a particular point in time, our study facilitates an understanding of how resource security has changed over the study period. The paper's second contribution is to establish the existence of statistically significant relationships between resource security and human development, population change, and violent internal conflict. This effort lays the groundwork for further investigations into the causal mechanisms and drivers of these relationships. Therefore, the inquiry is structured around the following four research questions:

1. How did resource security in terms of energy, food, and water evolve in the period from 2015–2019?
2. How does resource security relate to the state of human development globally?
3. What was the relationship between trends in resource security and population growth over the observed period?
4. What, if any, relationship exists between resource security and internal conflict risk?

2. Methodology

The analysis in this paper primarily uses data from the RAND Food–Energy–Water FEW Index. Initially developed in 2015 and extended in 2023 to include time-series data, the FEW Index tool measures and visualizes resource insecurity in terms of energy, food, and water security [1].

The tool features three tiers of calculation. The overall FEW Index is calculated for each country as the geometric mean of three subindexes that represent the individual resources, namely the Food, Energy, and Water Subindexes. Each subindex in turn is calculated as the geometric mean of resource availability, resource accessibility, and, in the case of water, resource adaptive capacity. The three dimensions of resource security, namely Availability, Accessibility, and Adaptive Capacity, are measured using a variety of development indicators specific to each resource. The index and each subindex are normalized to a scale of 0–1 with 1 indicating greater levels of resource security. Details of the index metrics and calculation methods are presented in Tariq et al. [15].

The extended FEW Index tool also includes estimated trends in food, energy, and water security for each country over the 2015–2019 period. To assess the magnitude of these trends, the available data for each country are fit to linear models that are used in turn to predict the index values for that country in the first available year (generally 2015) and the last available year (generally 2019) [15]. The difference between the two values is then converted to a percentage change via the following formula:

$$Percentage\ change\ in\ index = 100 * \frac{Predicted\ 2019\ index\ value - Predicted\ 2015\ index\ value}{Predicted\ 2015\ index\ value}$$

It is difficult to gather meaningful insight from trends over this short 5-year period for a specific country. However, we examined whether relationships exist between these temporal trends and other country-level data across large numbers of countries to identify insights about relationships between resource insecurity and other factors affecting human development, population, and internal conflict.

To investigate the relationship between resource insecurity and conflict risk, we used a conflict risk data index. The INFORM model calculates humanitarian risk in three dimensions: hazards and exposure, vulnerability, and lack of coping capacity. One of the inputs to the hazards and exposure dimension measure is 'GCRI derived High Violent Internal Conflict probability'; as the name suggests, it is derived from the Global Conflict Risk Index (GCRI), which uses open-source data to estimate the statistical likelihood of violent internal conflict in a country within the next four years and assigns scores on a scale from 0–10 [16]. GCRI focuses exclusively on internal conflict, i.e., intrastate conflict in which one or both of the belligerents are non-state actors [17].

The breakdown of resource security trends by region is a key component of our analysis; therefore, we assigned countries to regional groupings based on the convention used by the UN Statistics Division in the 2019 SDG Report [18]. This results in the following seven geographic regions:

1. Sub-Saharan Africa
2. Northern Africa and West Asia
3. Central and South Asia
4. East and Southeast Asia
5. Latin America and the Caribbean
6. Oceania
7. Europe and North America

We conducted two types of analysis to answer this study's research questions. The bulk of the analysis consisted of examining the relationship between measures of resource security such as the FEW Index or change in FEW Index and other variables such as the Human Development Index (HDI) and population growth. To assess the strength and direction of these relationships, we calculated the Pearson correlation coefficients for each pair of variables that were considered. We also conducted a descriptive analysis

that assessed the trends in the FEW Index and its subindexes over the study period and the variance in these trends across regions and countries with different levels of internal conflict risk.

3. Results

3.1. Trends in Resource Security (2015–2019)

Figure 1 shows the regional trends in the FEW Index and its component subindexes over the 2015–2019 period in the form of box plots. At a global level, we find that overall, resource security registered slight improvements, with a worldwide media FEW Index improvement of 2.61% and the median country in six out of the seven regions also witnessing improvements in FEW security. However, we observed significant variations when decomposing the trends regionally. In Oceania and Europe and North America, there was little change in the FEW Index and virtually every country in those regions witnessed improvements in FEW security. Sub-Saharan Africa, however, emerges as a region of considerable disparities. This was the only region that generally regressed on the FEW Index, with the median country, South Africa, witnessing a decline in the FEW Index of 3%. However, some Sub-Saharan countries such as Mauritius and Togo also registered significant improvements of up to 5%. Three other regions, namely North Africa and West Asia, Latin America and the Caribbean, and Central and South Asia mirror the same trend, albeit in a less extreme manner. The median change in FEW is slightly positive for all three regions, and they also include both countries that have improved and declined significantly in terms of FEW security. In East and Southeastern Asia, FEW security generally improved, and even straggler countries in this regard did not witness a FEW Index decline greater than 2%.

Figure 1. Trends in the Food–Energy–Water (FEW) Index and its subindexes over 2015–2019, by region. The left and right boundaries of the box in each plot represents the first and third quartiles of the data respectively, while the line inside the box represents the median of the distribution. Outside the box, the left and right 'whiskers' represent the minimum and maximum values in the distribution that are not considered outliers. In some of the plots, there are dots beyond the whiskers that represent outlier values.

Narrowing our focus to energy, energy security generally improved on a global scale with a median improvement of around 3.2%. This trend was mirrored at a regional level, with every region observing at least a modest improvement on this metric, though there were considerable differences in the magnitude of improvement. As before, Sub-Saharan Africa continued to exemplify extreme trends. The median Sub-Saharan African country, Mauritania, improved by 5.8% on the Energy Subindex, and most regional countries witnessed some degree of improvement in energy security. However, this region also contained countries such as the Central African Republic, which slid on the Energy Subindex by up to 10%. Two other regions, Central and South Asia and East and Southeast Asia also considerably improved in terms of energy security. While the remaining four regions; namely North Africa and West Asia, Europe and North America, Latin America and the Caribbean, and Oceania; witnessed minimal change in energy security.

The trends in food security tell a different story. At a global level, the changes in the Food Subindex are highly skewed, with a median improvement of over 6% but a mean improvement of only 1.3%. This is explained by the regional trends, particularly Sub-Saharan Africa, where even the median change in the Food Subindex is a decline of 17% I Burkina Faso. A few Sub-Saharan countries posted improvements, but the general trend was dismal, with over three-quarters of regional countries observing significant declines of 4% or more. Central and South Asia, East and Southeast Asia, and North Africa and West Asia also witnessed considerable variation in food security outcomes. However, the disparity between the best- and worst-performing countries is much less extreme than in Sub-Saharan Africa and each of those regions registered a positive median change in the Food Subindex. Europe and North America witnessed considerable improvements in food security and Latin America and the Caribbean also generally improved on the Food Subindex, though some countries among the latter witnessed precipitous declines of up to 30% on that measure.

Water security displays the most intriguing trends. At a worldwide level, there was little variation in the Water Subindex, with a median improvement of 0.72%, and the middle 90% of countries witnessed generally modest changes. Sub-Saharan Africa witnessed the greatest disparity in water security trends; over three-quarters of regional countries witnessed some degree of decline in water security, but the same region also contained some of the most improved countries globally. Three other regions, namely Central and South Asia, North Africa and West Asia, and East and Southeast Asia, witnessed similar trends with the median country in each region observing a modest decline in the Water Subindex. However, the range of outcomes in each region was much narrower than in Sub-Saharan Africa. The remaining regions observed few to no changes in water security.

3.2. Relation between Resource Security and Human Development

At a global level, FEW Index and HDI ratings from 2019 exhibit a strongly positive and statistically significant correlation of 0.87. The three subindexes were also positively correlated with HDI to a statistically significant degree at the global level, though HDI's correlation with the Water Subindex (0.55) was noticeably weaker than with the Energy and Food Subindexes (0.91 and 0.90 respectively). Upon further investigation, it appears that the lower correlation of HDI with the Water Subindex appears to be driven mainly by a lower correlation with water adaptive capacity (0.09), which reflects available renewable water resources in a country, rather than household access (0.84) and availability (0.80).

To discount the possibility that this relationship was mainly driven by the income component of HDI, we calculated the correlation between the FEW Index and the income component, measured in terms of gross national income per capita (GNIPC). We found that the FEW Index and GNIPC were strongly and significantly related positively, but the strength of the correlation was lower than for the relationship between FEW Index and overall HDI. These results are shown in Table 1 below.

Table 1. Correlation results at the global level for Human Development Index (HDI) and gross national income per capita (GNIPC) in 2019 with the Food–Energy–Water (FEW) Index and subindex values in 2019.

Index	HDI (2019)	GNIPC (2019)
FEW Index 2019	0.8664 ***	0.6547 ***
Energy Subindex 2019	0.9180 ***	0.6711 ***
Food Subindex 2019	0.9010 ***	0.7491 ***
Water Subindex 2019	0.5529 ***	0.3387 ***

Table note: *** $p < 0.01$.

These relationships are also generally reflected at the regional level. In every region, FEW Index and HDI in 2019 were positively correlated to a statistically significant degree; in most regions, the strength of the correlation was also similar to the global level, though the relationship was much weaker in North Africa and West Asia and Europe and North America, where the correlation coefficients were 0.56 and 0.36 respectively. The Energy and Food Subindexes was also correlated strongly, positively, and significantly with HDI in every region and these relationships exhibited less variation than in the case of the FEW Index. The Water Subindex was also positively correlated with HDI in most regions, but the relationship was much weaker than with the other subindexes, and many of these correlations were not statistically significant. Only three regions, namely Sub-Saharan Africa, Oceania, and Latin America and the Caribbean, observed strong, positive, and significant correlations with HDI; the relationship in other regions ranged from weakly negative to weakly positive, and none of the results were significant at a 5% level.

3.3. Relation between Trends in Resource Security and Trends in Population Growth

We find that globally, recent changes in the FEW Index and its subindexes are moderately correlated with population growth over the same period and these results are statistically significant. Improvements in the FEW Index, Food Subindex, and Water Subindex are negatively correlated with population growth, with coefficients of −0.47, −0.49, and −0.31, respectively. On the other hand, improvement in the Energy Subindex is weakly positively related to population growth with a coefficient of 0.28. These results are displayed in Table 2.

Table 2. Correlation results at the global level for population growth with trends in the Food–Energy–Water (FEW) Index and its Subindexes over 2015–2019.

Index	Percent Change in Population
Percent change in FEW Index	−0.4724 ***
Percent change in Energy Subindex	0.2754 ***
Percent change in Food Subindex	−0.4944 ***
Percent change in Water Subindex	−0.3077 ***

Table note: *** $p < 0.01$.

The results at the regional level are much more varied and less statistically significant. Change in the overall FEW Index tended to be weakly or moderately negatively related to population growth, though only one of the regions, Europe and North America, reported a statistically significant result. In Latin America and the Caribbean, the relationship was moderately positive, but the result was also not statistically significant. In the case of the Energy Subindex, the results are even more fragmented; in North Africa and West Asia and Sub-Saharan Africa, we found little to no correlation between changes in the Energy Subindex and population growth, though these results were statistically significant. In Central and South Asia and North America and Europe, these variables were negatively correlated, with the latter result also statistically significant. The remaining regions observed a weak to moderate positive relationship between these two variables, though only one result, from Latin America and the Caribbean, was statistically significant.

None of the regions reported a statistically significant correlation between change in the Food Subindex and population growth, though in all regions except Latin America and the Caribbean and Oceania, the relationship was negative. Change in the Water Subindex was also generally associated negatively with population growth across six regions, though this finding was only statistically significant for Europe and North America and Sub-Saharan Africa. In Central and South Asia, there was little to no relationship between the variables.

3.4. Relation between Trends in Resource Security and Internal Conflict Risk

We were also interested in learning about whether there was a relationship between internal conflict risk and FEW security and, if so, how this relationship related to trends in FEW security over the 2015–2019 period. After examining the distribution for FEW security, we observed a discontinuity between higher and lower resource-secure countries (see Figure 2). We also observed bimodality in the distribution for internal conflict risk; most countries reflected either very high or very low conflict risk ratings with little middle ground. As a result, analysis of how FEW security relates to conflict risk reveals four categories of countries, those with:

1. High conflict risk and low FEW Index
2. High conflict risk and high FEW Index
3. Low conflict risk and high FEW Index
4. Low conflict risk and low FEW Index

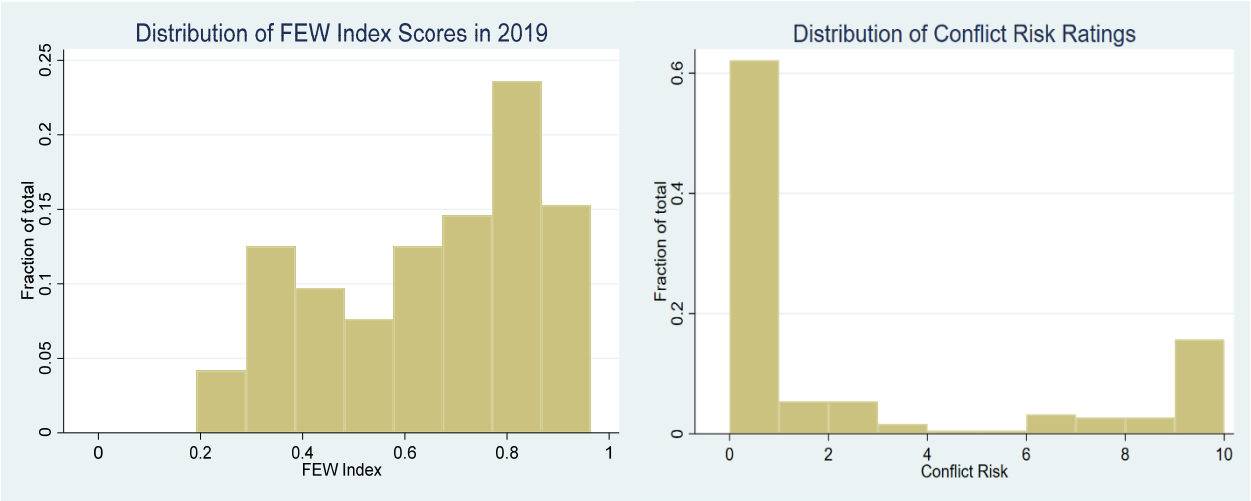

Figure 2. Distribution of Food–Energy–Water (FEW) Index and Conflict Risk ratings.

Therefore, we established four conflict risk–resource security categories and assigned each country for which a conflict risk rating and a FEW Index score in 2019 were available to one of these categories using criteria that emerged from the distributions of each index. Countries with a conflict score of 6 or more were judged to be conflict-prone, while countries with a score of less than 6 were conflict-free. Similarly, countries with a FEW Index of 0.6 or higher were judged to be resource-secure while countries with lower scores were assessed as resource-insecure.

Figure 3 shows the trends in FEW Index and subindexes of countries when categorized by internal conflict risk and FEW security. We observe that, in general, countries assessed to still be resource-insecure in 2019 witnessed smaller FEW improvements than other countries since 2015; this effect was further magnified if the country was also conflict-prone. More than half of countries that were conflict-free but resource-insecure witnessed declines in the FEW Index with the median country declining by 0.43%, as did over three-quarters of countries that were both conflict-prone and resource-insecure with a media FEW decline

of 5%. In contrast, most countries that are already FEW-secure recorded improvements on the FEW Index, regardless of how conflict-prone they are.

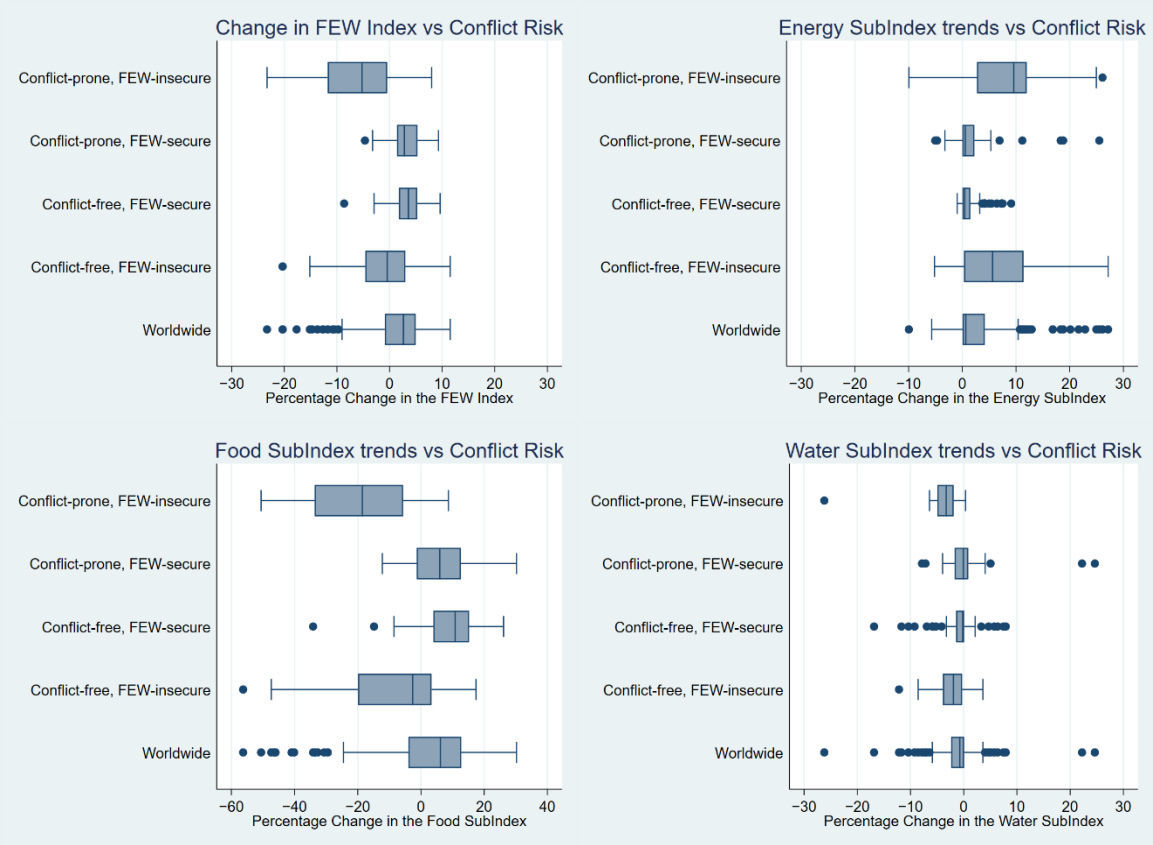

Figure 3. Trends in the Food–Energy–Water (FEW) Index and its subindexes, by conflict risk–resource security category. The left and right boundaries of the box in each plot represents the first and third quartiles of the data respectively, while the line inside the box represents the median of the distribution. Outside the box, the left and right 'whiskers' respectively represent the minimum and maximum values in the distribution that are not considered outliers. In some of the plots, there are dots beyond the whiskers that represent outlier values.

Narrowing our focus to the subindexes, the trends are mixed. Regarding energy, most countries across all four categories recorded improvements in the Energy Subindex, but resource-insecure countries tended to improve much more significantly, with a median improvement of nearly 10%, while resource-secure nations witnessed modest improvements. Food security was a different matter, with most resource-secure countries witnessing further improvements while most resource-insecure nations worsened on the Food Subindex. Conflict risk did not appear to have a major impact on the performance of resource-secure states, but among countries that were resource-insecure, those that were also conflict-prone tended to decline more significantly than those in the conflict-free group, with median Food Subindex declines of 18% and 2% respectively. There was little variation in Water Subindex trends, both within and across categories, but resource-insecure states tended to decline to a slightly greater extent than resource-secure nations. As with energy, internal conflict risk does not appear to be a major driver of the observed trends for water security.

The situation especially dire in a set of 19 countries that were found to be both conflict-prone and resource-insecure in terms of FEW security in 2019; Figure 4 shows the geographic distribution of these countries, which were mostly found in South Asia and Sub-Saharan Africa. Figure 5 shows their performance in 2019 on the FEW Index and its subindexes. As the figure shows, these countries lag behind the rest of the world in terms of

overall FEW security and water security, and aside from two instances, also remain behind in terms of Energy security. Worryingly, many of these nations regressed further during the 2015–2019 period, particularly in terms of Food and Water security, as can be seen in Figure 6. Five other countries, Burundi, Libya, Mozambique, Niger, and Uganda, were also found to be conflict-prone, and although there were insufficient data to calculate the FEW Index for these countries during the study period, they would also be classified as resource-insecure per the previous iteration of the RAND Food–Energy–Water Index.

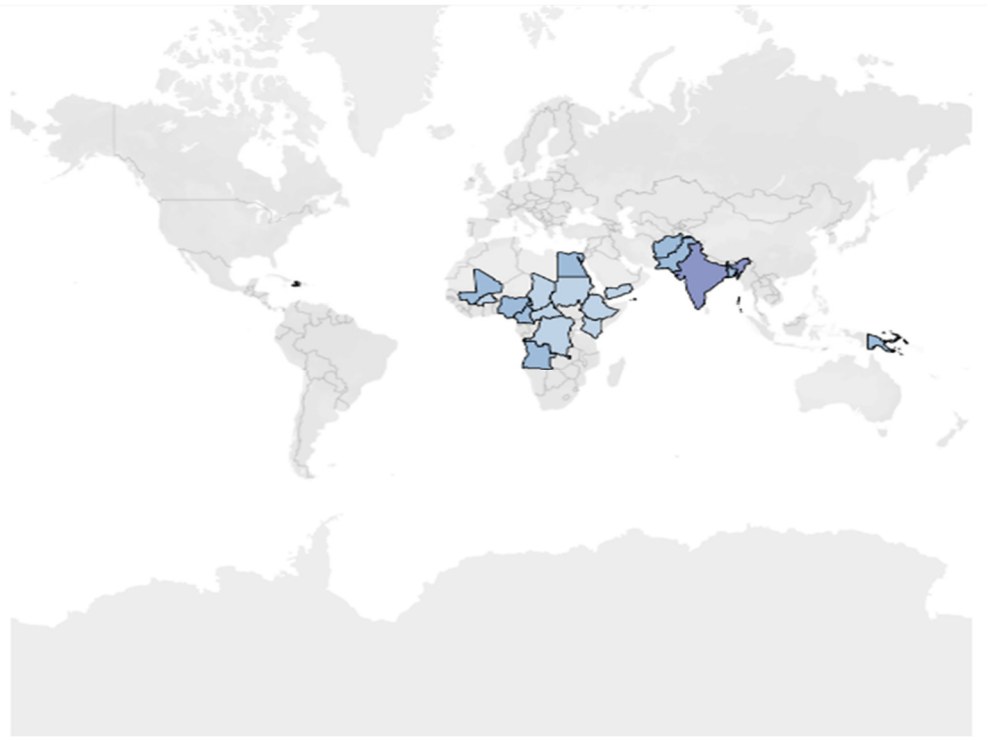

Figure 4. Map View of conflict-prone and resource-insecure nations [15].

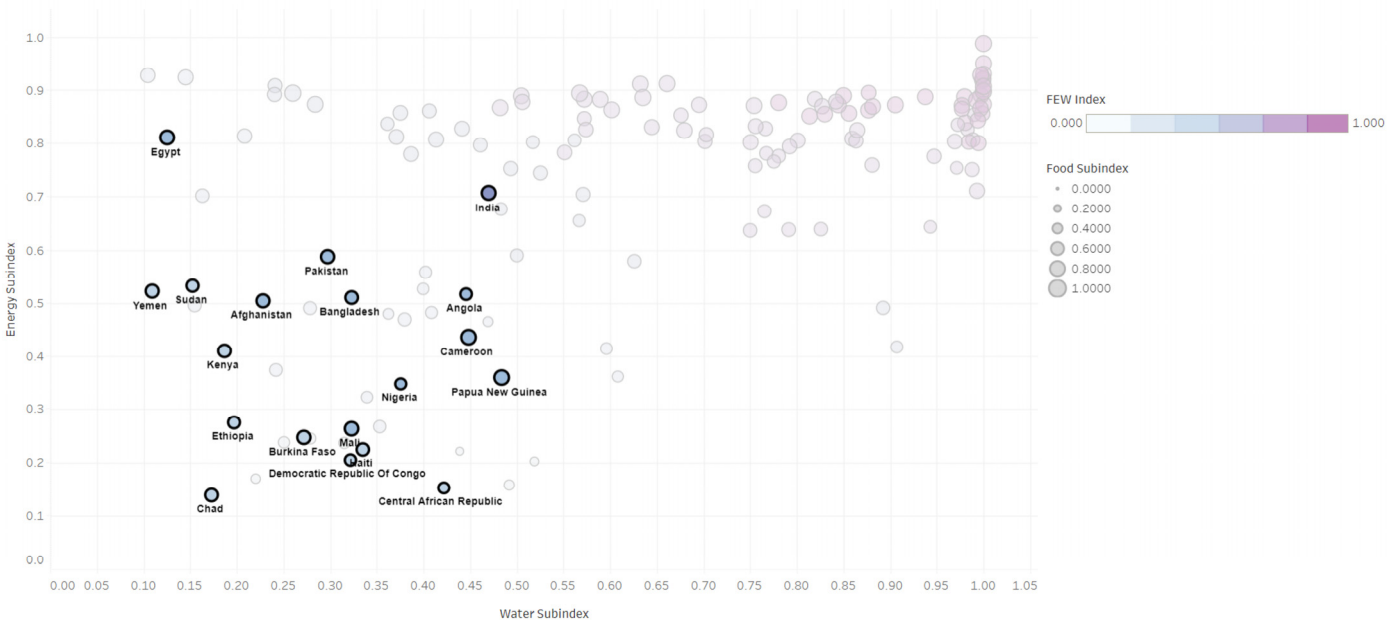

Figure 5. Food–Energy–Water (FEW) plot of conflict-prone, FEW-insecure nations compared against other countries [15].

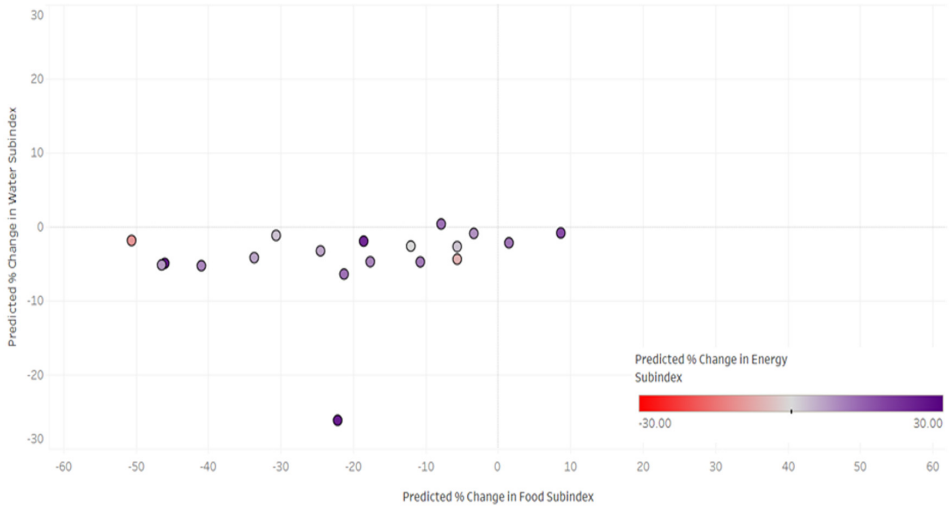

Figure 6. Trends in the Food–Energy–Water (FEW) Index and its subindexes for conflict-prone, FEW-insecure nations over 2015–2019 [15].

4. Discussion

The analysis in this study was geared towards answering four research questions presented in the introduction. Based on our results, we reach the following conclusions:

Conclusion 1: **On balance, overall resource security has improved modestly on a global level, driven mainly by significant improvements in energy security and, to a lesser extent, food security.** Worldwide, the media FEW Index change saw an improvement of 2.6%, while the median change in the Energy, Food and Water Subindexes saw increases of 0.6% and 6%, and a decline of 0.72%, respectively. In terms of effect distribution, over 75% of countries across the globe improved in terms of energy security but over 75% of nations also witnessed declining water security; further, while more countries improved on the Food Subindex than those that did not, the latter group contains some states where food security dropped precipitously, with some witnessing declines in the Food Subindex by 20% or more.

Conclusion 2: **We find that, globally, resource security is strongly associated with human development as measured by HDI, with a FEW Index–HDI correlation of 0.866.** In addition to verifying results from the original FEW study, we also find that this association is not simply driven by the income component of the HDI, as the correlation between FEW Index and gross national income per capita (0.655) is smaller than the FEW Index-HDI correlation. One interesting finding from this analysis was that human development is less associated with water security than other types of resource security. This was found to be driven by a minimal association between human development and the per capita internal renewable water reserves available to a country; in our assessment, this effect likely stems from the existence of several countries such as Kuwait that are small in size, densely populated, and located in drier regions, but are nevertheless highly developed.

Conclusion 3: **At a global level, worsening resource security is moderately associated with higher population growth.** Except for the Energy Subindex, the FEW Index and its subindexes are all negatively associated with population growth, with correlation coefficients of −0.47, −0.49, and −0.30 respectively. Although regional results tended to lack statistical significance, their directionality for each index tended to mirror the global trend. This implies that countries with high rates of population growth are likelier to observe increasing FEW insecurity and that a growing proportion of the global population is living in conditions of resource insecurity.

Conclusion 4: **Internal conflict risk has a significant effect on resource security in countries that are already resource-insecure.** Most countries that were categorized as FEW-insecure underperformed the median global FEW improvement of 2.61%; however, the median conflict-free, FEW-insecure country declined on the FEW Index by 0.43%,

while the median conflict-prone, FEW-insecure nation observed a decline of 5.2%. The gap between these two categories is also consistent, with over 75% of conflict-prone, FEW-insecure nations underperforming the median country in the former group. However, among countries that were rated as resource-secure, internal conflict did not appear to play a significant role; the distributions of FEW improvement for conflict-free, FEW secure and conflict-prone, FEW-secure states were extremely similar and the median country in both groups slightly outperformed the global median in FEW improvement.

The analysis in this study is limited in two ways. First, we report correlations rather than causal relationships, thus limiting the extent to which drivers of improvement or regression in resource security can be identified through this analysis. Second, complete FEW data for each year during the study period were missing for several countries, limiting our ability to draw country-specific conclusions and make cross-country comparisons.

Despite these challenges, by observing regional and global results in aggregate, we are able to discover several thought-provoking trends. The finding that most regions are becoming more resource-secure over time is certainly positive; however, the disparity among regions is stark and is growing, as evidenced by Sub-Saharan Africa's decline on the FEW Index and most of the Subindexes. Countries that were already struggling with food and water security are regressing even further and when combined with the findings that HDI and population growth are strongly associated positively and negatively respectively with resource security, it leads to the disquieting conclusion that despite considerable efforts to promote sustainable development, the proportion of the global population living in resource insecurity continues to grow.

These results provoke several questions about the drivers of resource security, chiefly what caused some countries to regress so greatly in terms of food and water security while outperforming the rest of the world in improving energy security. We discuss some hypotheses below that we believe would be useful to investigate as extensions of this work.

One possible driver of this disparity is climate change. Our analysis found that resource security is highly correlated with human development, including per capita income. Low-income countries also suffer disproportionately from the effects of climate change. Changing weather patterns and increasing incidence of extreme weather events such as droughts can exacerbate water scarcity in countries that are already water-insecure [19]. Shrinking water resources are also projected to increase the likelihood of crop failures [20]; this may be extremely pertinent in the case of sub-Saharan Africa, where a substantial proportion of crops are irrigated by rainfall [21]. A disruption in rainfall patterns and heat stress due to rising temperatures could be devastating for food security in food-insecure nations by reducing crop yields in climate-affected countries and also raising prices worldwide, which would hit low-income countries especially hard [22].

Another possible explanation for these results is the renewable energy transition. Sub-Saharan Africa in particular faces key energy security challenges, driven mainly by a lack of access to clean cooking technologies and low electrification rates. Progress is slow in terms of clean cooking, with the rate of population growth exceeding efforts to promote improved cooking technologies [23]. However, there has been tremendous recent progress in the expansion of access to energy, driven by ambitious government policies and the increasing competitiveness of renewable technologies with traditional forms of power generation. The cost of utility-scale solar PV and wind energy declined of over 60% between 2010 and 2019, making them viable options to displace the regions traditional reliance on hydropower and thermal energy [24]. Progress in regional electrification is also related to supportive policy environments in certain countries such as Kenya, where solar products are exempt from import duties and value-added taxes [23]. These developments could explain why low-income countries, many of whom have considerable renewable energy potential, are struggling with food and water security but are progressing rapidly in energy security.

Financing and foreign investment may also help shed light on these findings. Literature on the effects of foreign investment indicates that inflows of foreign direct invest-

ment (FDI) exacerbate inequality in countries with high political, financial, and economic risks [25]. Our findings also suggest that resource security worsens in countries at high risk of violent internal conflict, leading to the question of whether FDI plays a role in mediating this relationship. Other studies have shown that in Sub-Saharan African countries, FDI and foreign aid inflows have a negative impact on poverty alleviation efforts [26]. As we found that resource security is highly correlated with human development, which includes per capita income, these results highlight an intriguing question about the precise relationship between foreign capital inflows, resource security, and conflict risk. The impact on monetary policies in developed countries is also salient, as foreign investment in lower-income jurisdictions is dependent on monetary policies in wealthier nations, such as interest rates.

The nexus between resource security and internal conflict risk is also significant, with renewed efforts across the globe to combat instability, improve economic and security outcomes, and promote democratic values. For instance, the United States is engaging in ten-year partnerships with nine priority countries under the U.S. Strategy to Prevent Conflict and Promote Stability with the objective of improving stability and resilience in regions vulnerable to conflict [27]. These nine countries, as well as countries that were assessed as conflict-prone and resource-insecure in our analysis, are listed in Table 3, which illustrates considerable overlap between the two groups. One key observation is that all the U.S. partner countries are resource-insecure, but many are not conflict-prone despite the strategy's emphasis on reducing conflict. The provision of aid and the final selection of partner countries is certainly subject to many factors beyond need; however, we posit that the resource security–conflict risk nexus may provide useful guidance for directing future development efforts by identifying countries that are at the greatest risk of instability.

Table 3. List of countries identified as risk-prone and/or selected for U.S. Strategy to Prevent Conflict and Promote Stability, by conflict risk and resource security ratings.

Country Name	Conflict-Prone	Resource-Insecure	Included in U.S. Strategy
Afghanistan	Yes	Yes	No
Angola	Yes	Yes	No
Bangladesh	Yes	Yes	No
Benin	No	Yes	Yes
Burkina Faso	Yes	Yes	No
Burundi	Yes	Yes *	No
Cameroon	Yes	Yes	No
Central African Republic	Yes	Yes	No
Chad	Yes	Yes	No
Cote D'Ivoire	No	Yes	Yes
Democratic Republic of Congo	Yes	Yes	No
Egypt	Yes	Yes	No
Ethiopia	Yes	Yes	No
Ghana	No	Yes	Yes
Guinea	No	Yes *	Yes
Haiti	Yes	Yes	Yes
India	Yes	Yes	No
Kenya	Yes	Yes	No
Libya	Yes	Yes *	Yes
Mali	Yes	Yes	No
Mozambique	Yes	Yes *	Yes
Niger	Yes	Yes *	No
Nigeria	Yes	Yes	No
Pakistan	Yes	Yes	No
Papua New Guinea	Yes	Yes	Yes
Sudan	Yes	Yes	No
Togo	No	Yes	Yes
Uganda	Yes	Yes *	No
Yemen	Yes	Yes	No

Table note: Countries highlighted in **bold** are identified both as risk-prone by our analysis and as partners for the US strategy to Prevent Conflict and Promote Stability. Countries highlighted in *italics* are identified as partners in the strategy but are not risk-prone according to our analysis. For some countries, FEW data were unavailable for the 2015–2019 period, and their resource security ratings are based on data from the first iteration of the FEW Index. Those countries are identified with a * in the resource-security column.

We conclude that the FEW Index remains an indicator of development outcomes relevant to obtaining sustainable development goals. This work could be extended to better understand some of the relationships described in this paper, such as why food security has dropped so severely in some countries and not others, why the Energy Sub-index is positively correlated with population growth while the Water and Food Sub-index are negatively correlated, and why resource-insecure and conflict-prone countries appear to experience more pronounced declines in resource security. This work can also be extended in the future by further analysis of trends in FEW security with other threats and drivers of human development such as climate change, technological innovation, and migration, and with a closer examination of the causal links between these factors and FEW outcomes. Finally, research to connect this work with scenario exploration could help policymakers consider how development efforts, threats, and opportunities can improve resource security in the future.

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