# Warfare Ecology, RADs, and the Ukraine Conflict: Framing Remarks for Sustainability Science

## Part I

G. Machlis, Clemson University
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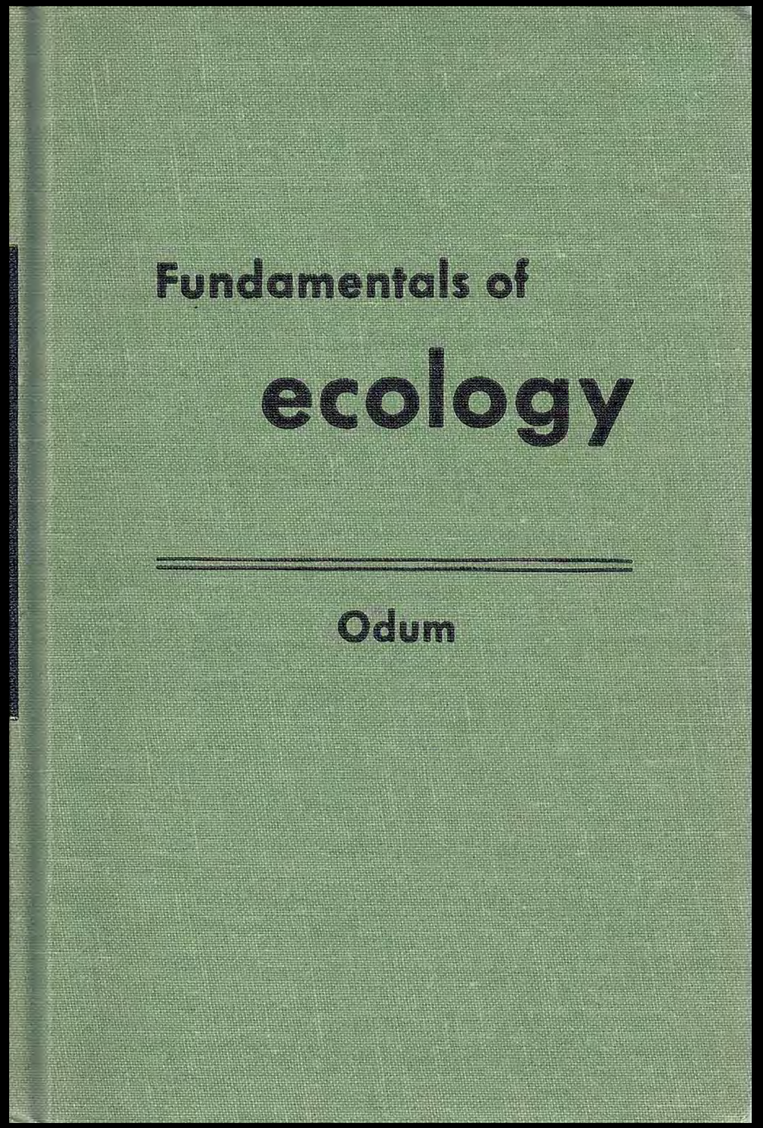
National Academies of Science, Engineering, and Medicine,  1 June 2022


Fundamentals of
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# Warfare Ecology

GARY E. MACHLIS AND THOR HANSON

*Among human activities causing ecological change, war is both intensive and far-reaching. Yet environmental research related to warfare is limited in depth and fragmented by discipline. Here we (1) outline a field of study called "warfare ecology," (2) provide a taxonomy of warfare useful for organizing the field, (3) review empirical studies, and (4) propose research directions and policy implications that emerge from the ecological study of warfare. Warfare ecology extends to the three stages of warfare—preparations, war, and postwar activities—and treats biophysical and socioeconomic systems as coupled systems. A review of empirical studies suggests complex relationships between warfare and ecosystem change. Research needs include the development of theory and methods for examining the cascading effects of warfare on specific ecosystems. Policy implications include greater incorporation of ecological science into military planning and improved rehabilitation of postwar ecosystem services, leading to increased peace and security.*

*Keywords: ecology, warfare, policy, conflicts, ecosystems*

**The scientific evidence that *Homo sapiens* is causing** unprecedented environmental change is now compelling (MEA 2003). Among human activities, war is common, almost constant, and sweeping in its ecological impact. There have been 122 armed conflicts around the world in the past

## A taxonomy of warfare

An accurate taxonomy of warfare is essential to the development of warfare ecology. The challenge is to integrate what Clausewitz described as "the grammar of war" with the concerns of ecosystem science. Military definitions of war—

*The stages of warfare…*

*Table 1. A taxonomy of warfare.*

| Key element | Stage of warfare | | |
|---|---|---|---|
| | **Preparations** | **War** | **Postwar activities** |
| Civilian | Propaganda, security alerts, civil defense training, militias | Rationing, refugees, casualties, loss of shelter and employment | Relocation, rehabilitation, illness, mortality, civil resistance |
| Military | Recruiting, conscription, training, mobilization | Campaigns, engagements, battles, casualties, prisoners of war, rehabilitation and treatment | Demobilization, occupation, reintegration, illness, mortality, peacekeeping |
| Materiel | Research and development, testing, manufacturing, strategic materials, stockpiling, positioning | Bombing, small-weapons firing, missiles, mines, supplies (petrol, ammunition, spare parts) | Unexploded ordnance, weapons disposal, cleanup, factory conversion |
| Infrastructure | Planning, energy and raw material supply, construction, maintenance, homeland security | Ports, supply depots, forts, bases, camps, hospitals, roads, emplacements | Reconstruction and recovery, decommissioning, base closures, economic restoration |
| Governance | Propaganda, policy, strategy, defense treaties, economic sanctions | Propaganda, civil control, alliances | Treaties, territorial exchange, reparations, war-crime trials |
| Diplomacy | Espionage, alliances, negotiations, sanctions, peacekeeping | Espionage, alliances and coalitions, negotiated surrender, cessation | Prisoner-of-war exchanges, occupation treaties, economic assistance treaties |

# *Keystone species…*

## A NOTE ON TROPHIC COMPLEXITY AND COMMUNITY STABILITY*

That "stability" is conferred approximately in proportion to the diversity of energy pathways characterizing any particular community is a axiom among ecologists. As examples of this belief, one can read lity increases as the number of links increase" (MacArthur, ) or "a rich fauna and flora . . . tends to be very stable because of ty of ecological checks and balances" (Watt, 1964, p. 1434). ars to be little or no sound evidence available to accept or reject nents, because an operational definition of stability is lacking, as om the more complex associations. The most workable definition tements about the relative variability of population numbers in r time, although limits on the extent of the spatial dimension are stated, and collections of acceptable data through time are tedi- er, and hence minimal. The basic data for a community tend to ists with comparisons and evaluations made between years on a absence basis, an analysis providing a measure of predictability, rily stability. At the population level the direction and magnitude numbers, that is, a measure of the tendency to oscillate, may be a measure. Even impressions based on the intuitive understanding of a competent naturalist may prove acceptable. Any or all of these would suffice for the present purpose, although they fail to make the critical

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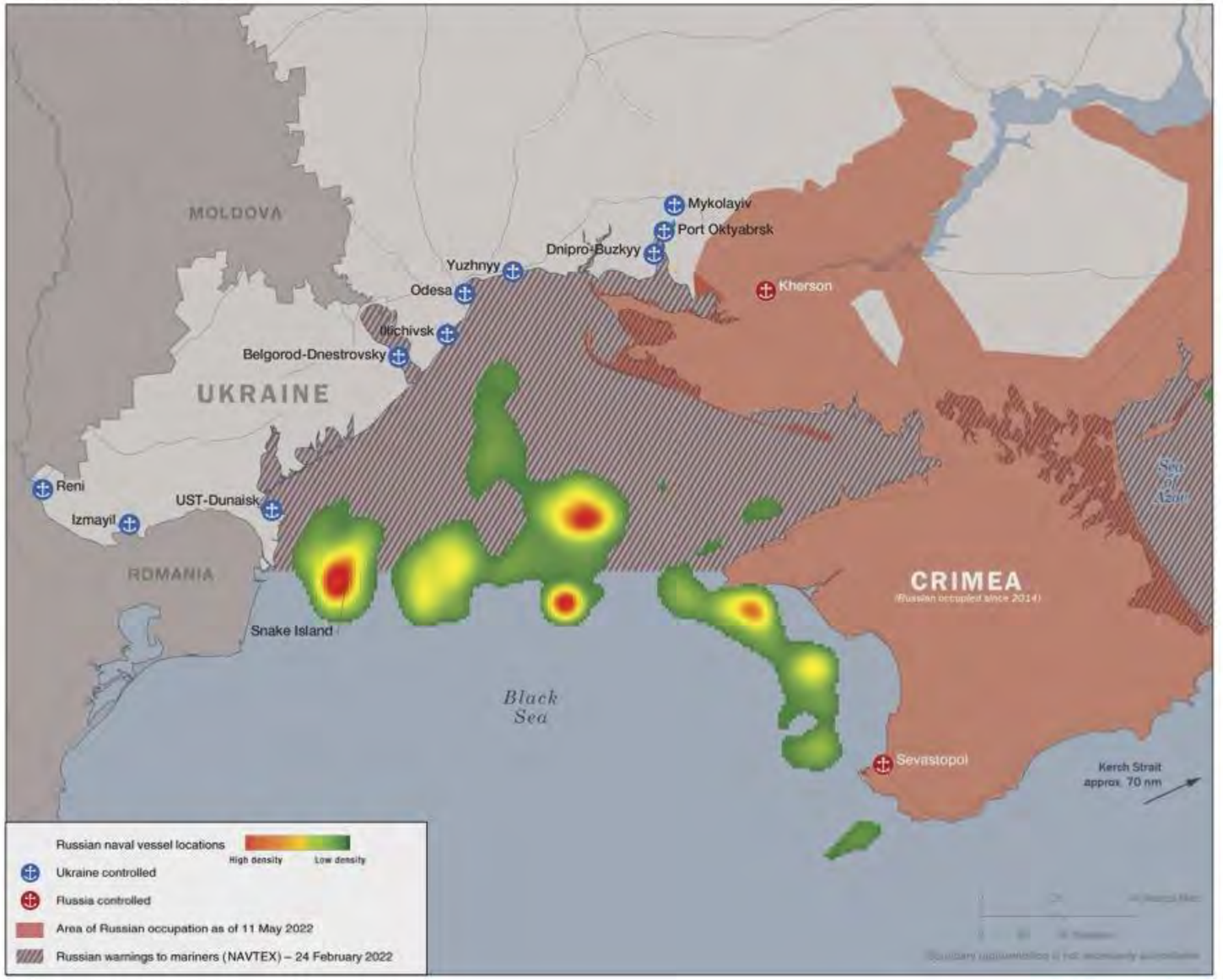
May 20, 1968

# Russia-Ukraine: Russian Naval Operations Demonstrate Intent to Control Access in Northwestern Black Sea, February–May 2022




Black Sea: Russian Naval Vessel

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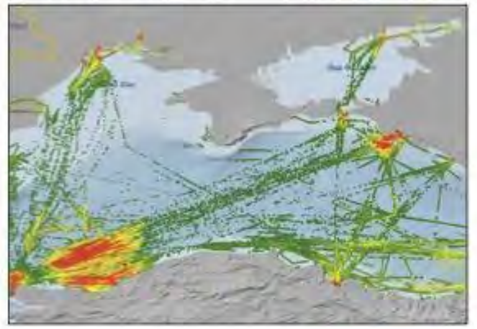
Pre-Invasion Civil Maritime Traffic

14 February–15 February 2022

High density Low density



Post-Invasion Civil Maritime Traffic

17 May–18 May 2022

High density Low density

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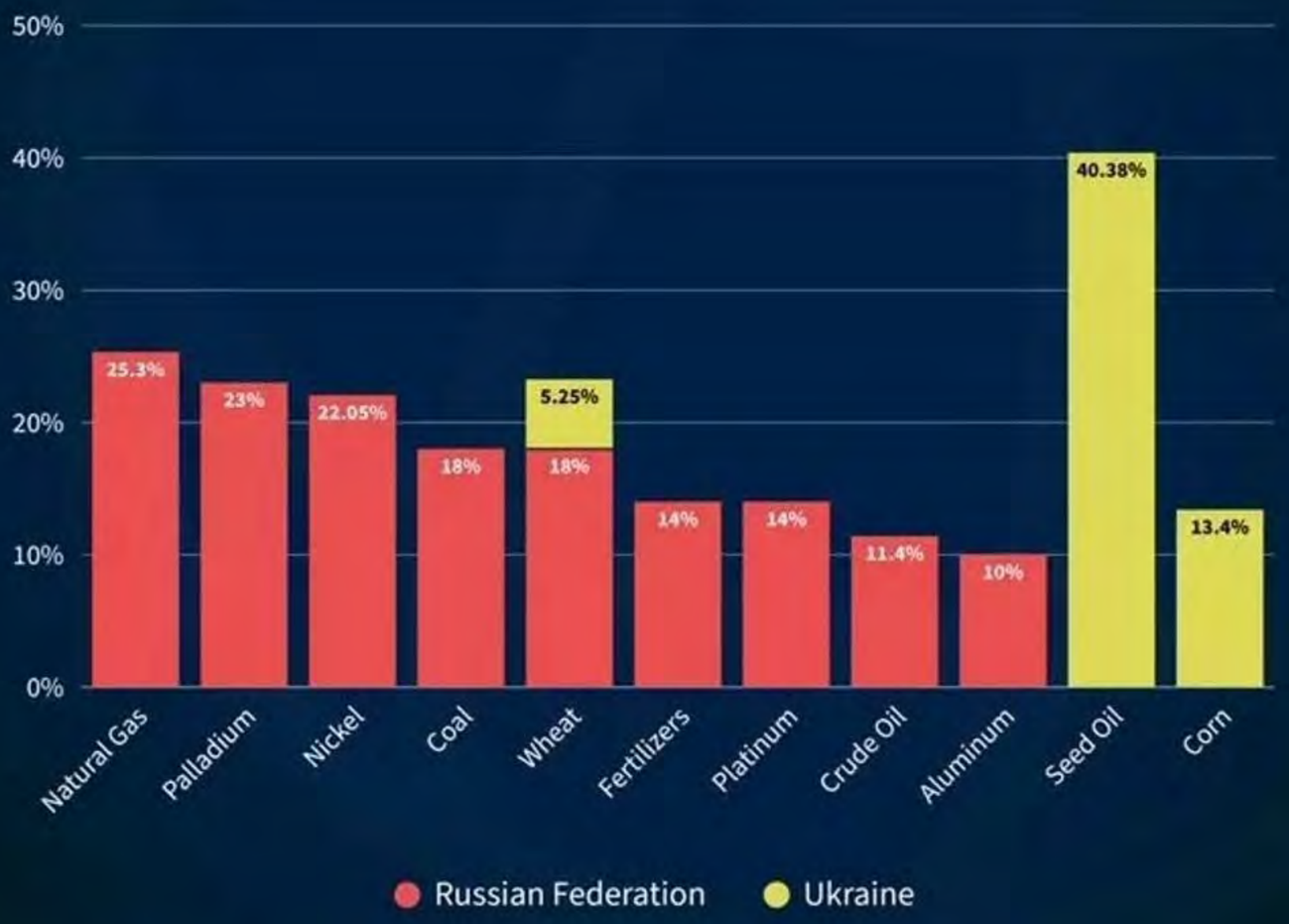
Equitable Growth, Finance & Institutions

# Shockwaves for global trade

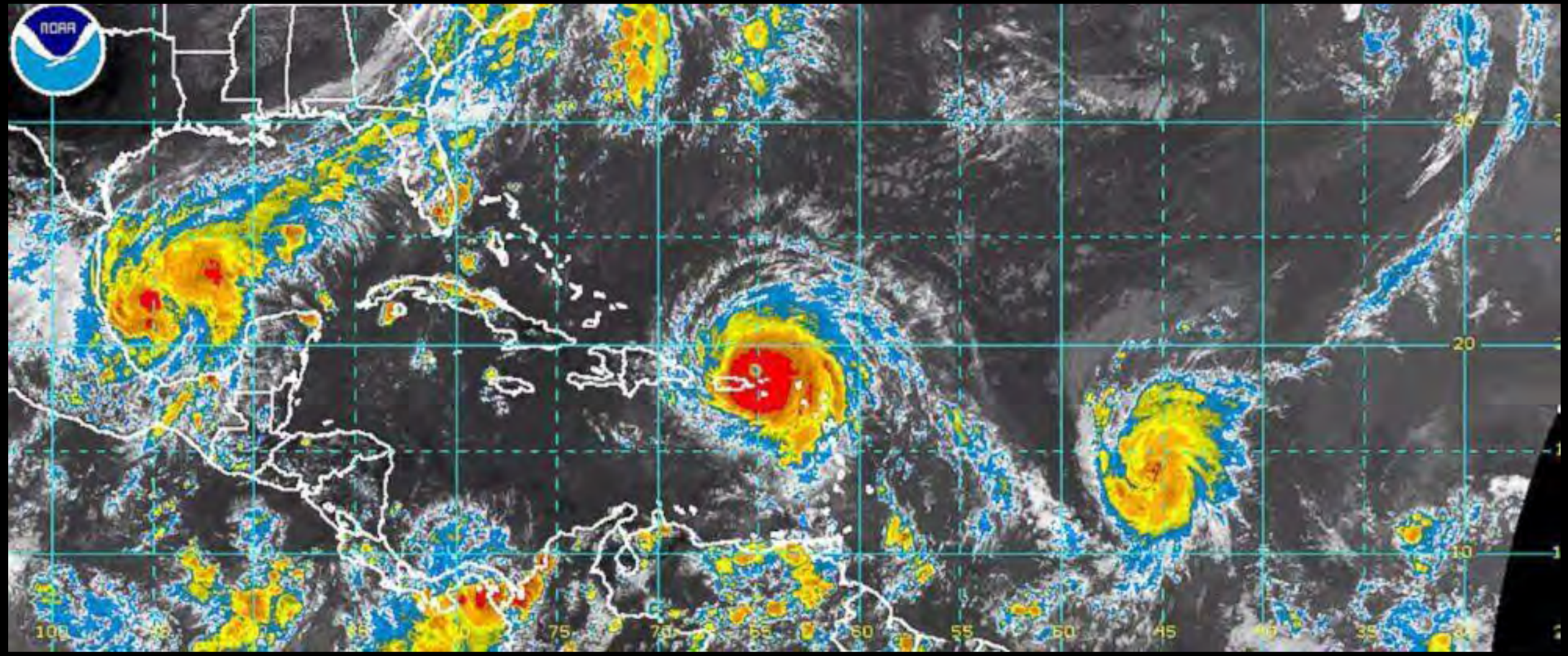
Some developing economies are heavily reliant on Russia and Ukraine for food

Ukraine and Russia's commodity exports as a percentage of global exports




Source: World Bank Analysis - March 2022

# *Recurrent acute disasters (RADs)…*



SCIENCE ADVANCES | RESEARCH ARTICLE

APPLIED ECOLOGY

# A framework for research on recurrent acute disasters

**Gary E. Machlis[1]*, Miguel O. Román[2], Steward T. A. Pickett[3]**

**Disaster science examines the causes, behaviors, and consequences of hazardous events, from hurricanes to wildfires, flooding, and major industrial accidents. Individual disasters are recurring more frequently and with greater intensity. Recurrent acute disasters (RADs) are sequential disasters that affect a specific locale over time. While disaster science has matured in recent years, understanding of the distinctive characteristics of RADs varies by discipline and lacks predictive power. A theoretical framework is presented by borrowing in part from mathematical topology and disturbance ecology. The recurrent disasters affecting Puerto Rico 2017–2020 are examined as a case example to test the framework. A key variable is the complex characteristics of legacy conditions created by one disaster that influence the effects of subsequent disasters. Substantial improvements in disaster response, recovery, and preparedness can be gained by adopting a RAD-based approach.**

*Legacy conditions…*

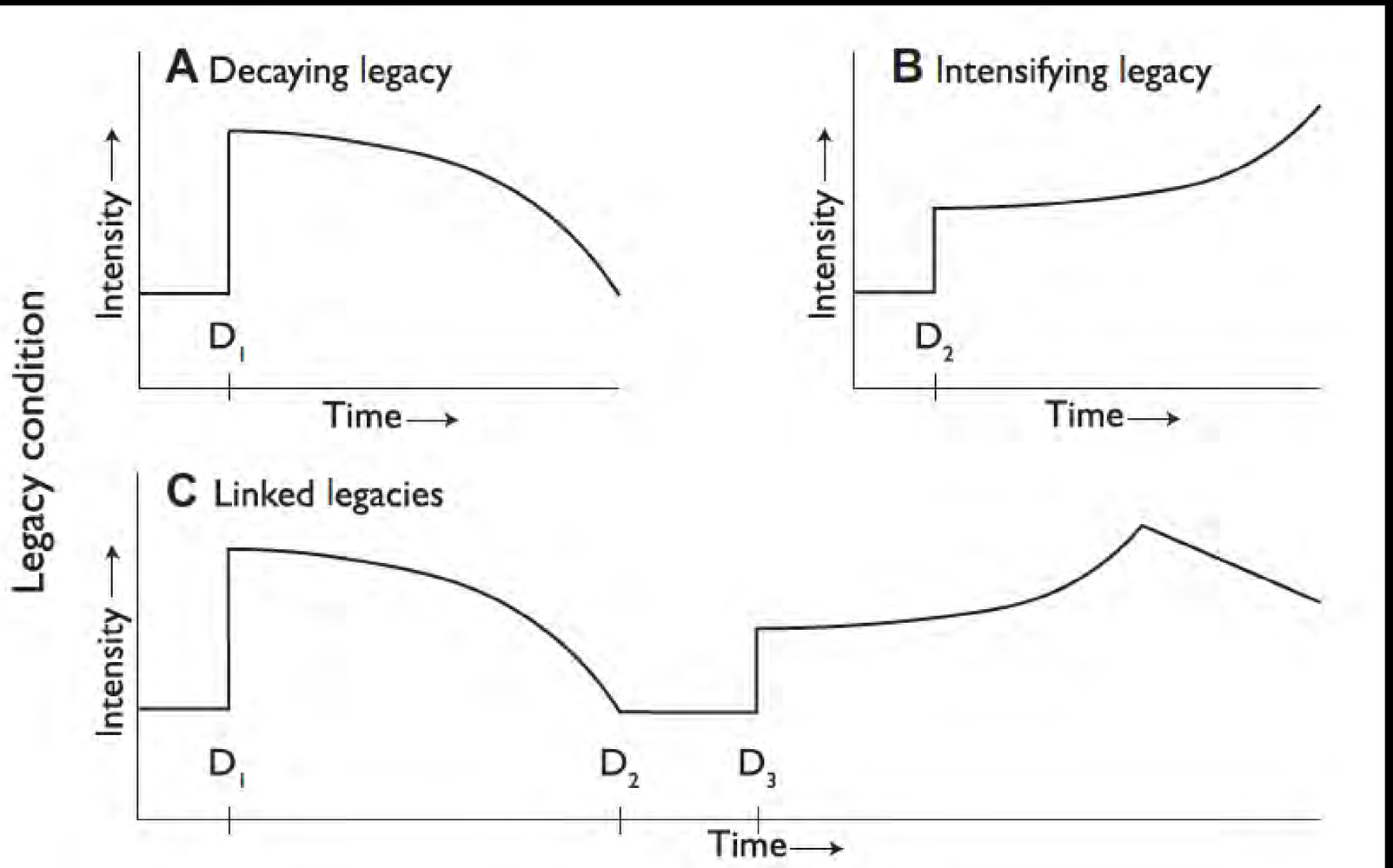
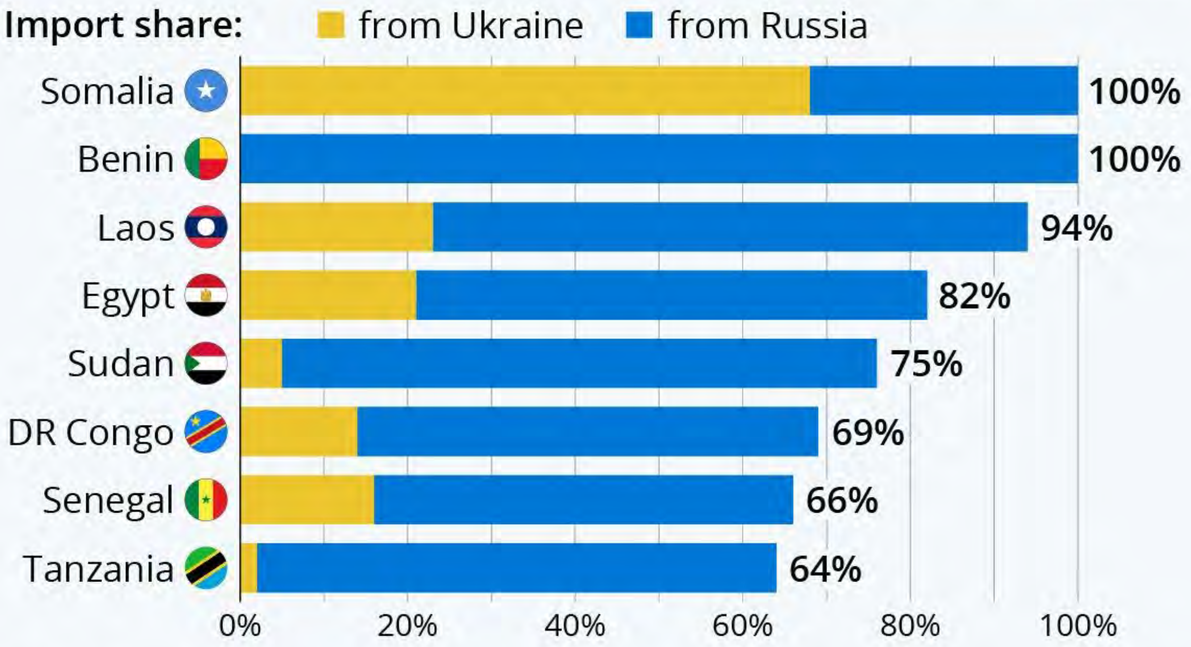



**Fig. 3. A general schema of several categories of legacy conditions.** (**A** to **C**) $D_1$ to $D_3$ represent RADs.

# The Most Vulnerable Countries Amid Wheat Shortages

Countries among the world's least developed which are most dependent on wheat imports from Russia and Ukraine (2020)




Least developed and/or African countries

Sources: UNCTAD, Statista


“Globalization is not a good thing; it’s a great thing. We come to the question, is it moving, is it pausing? I think it’s temporarily pausing. Our responsibility as leaders is to continue to ensure globalization keeps progressing, not because it is in the interest of the companies — which would be right anyway — but because it is the core interest of consumers.”

Loic Tassel, President
Procter & Gamble European Operations

*Sustainability for the forgotten…*

# Part I Implications for Sustainability and the Ukraine Conflict

- Extend analyses beyond economics to assess sustainability of social-ecological systems
- Assess keystone elements for vulnerabilities and potential resilience improvements
- Extend focus of concern to pre-war, war, and post-war conditions and consequences
- Document legacy conditions within a Recurrent Acute Disaster framework
- Work at scales beyond national to include regions, communities, households and persons
- Include the forgotten in advancing sustainability

# Warfare Ecology, RADs, and the Ukraine Conflict: Framing Remarks for Sustainability Science

## Part II

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G. Machlis, Clemson University

National Academies of Science, Engineering, and Medicine,  1 June 2022


Belarus Ukraine Border
51.5136 Lat | 29.850 Long
02/24/22 07:57:38 PM UTC
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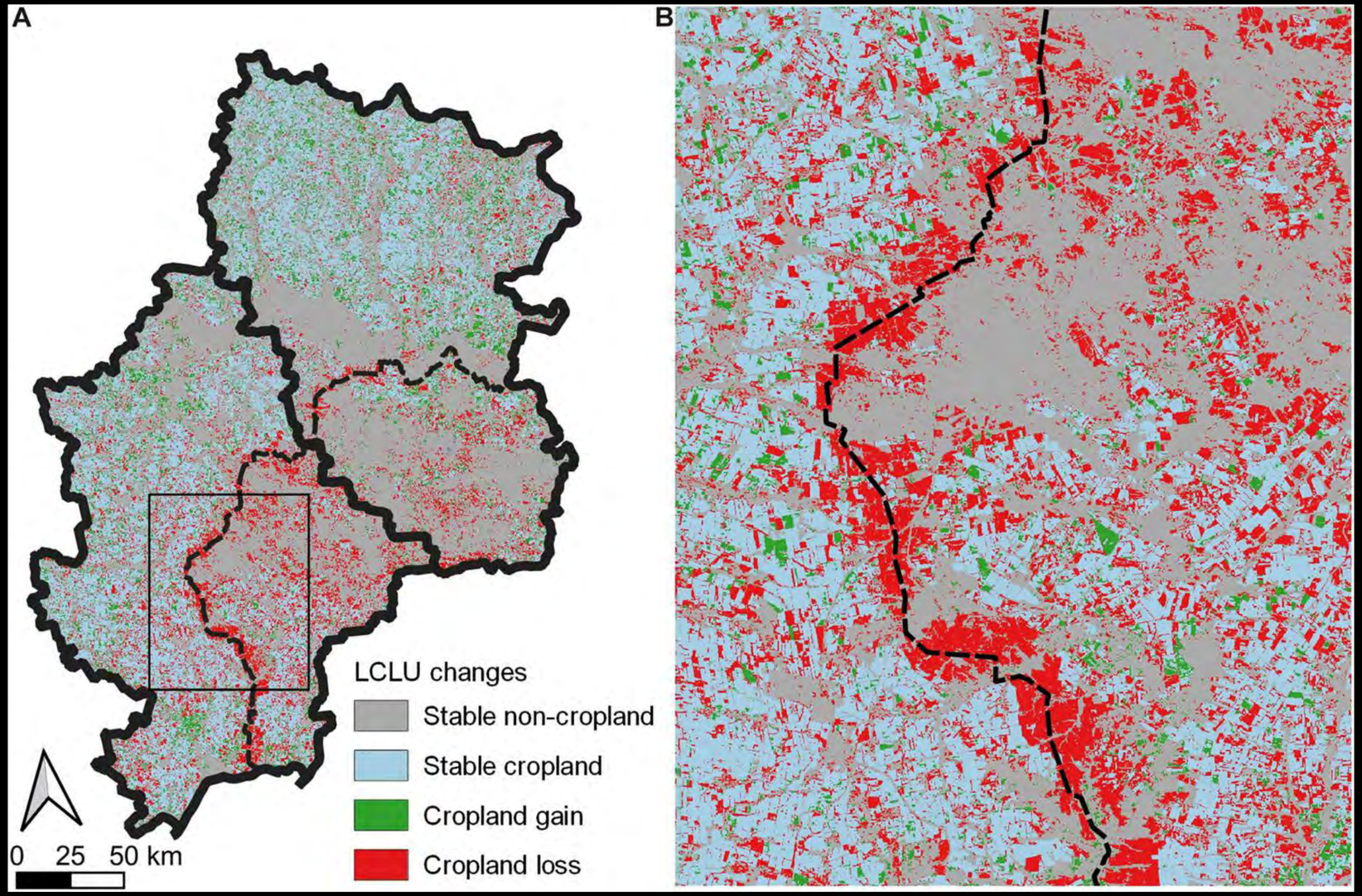
# *Legacy conditions…*

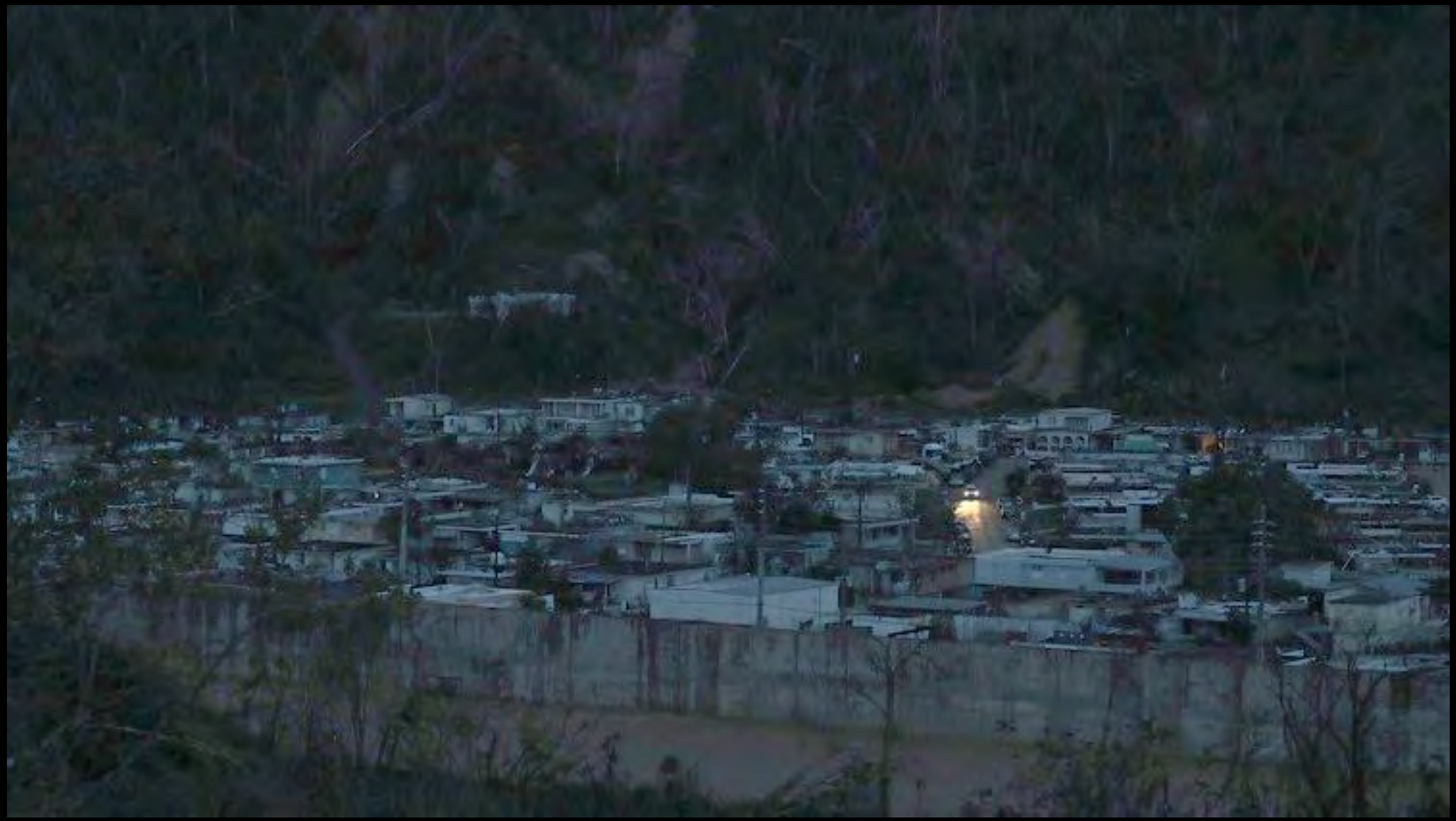
Aleppo Syria, 2013

Canóvanas Puerto Rico, 2017

# Cropland Losses in South-Eastern Ukraine since the Annexation of Crimea




**Credit: Skakun et al., (2019)**



National Aeronautics and Space Administration

NASA

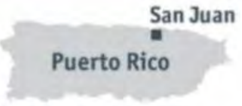
# Earth at Night

EXPLORE EARTH

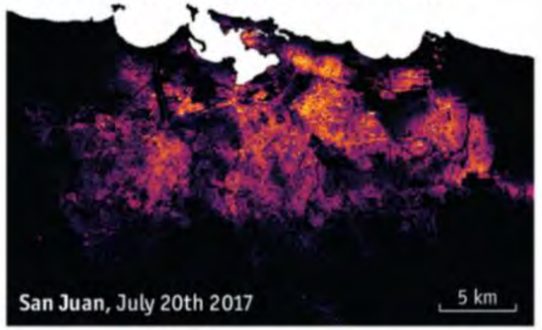
Román et al., (2018)
https://blackmarble.gsfc.nasa.gov/


## Illuminating

Night-light intensity in San Juan

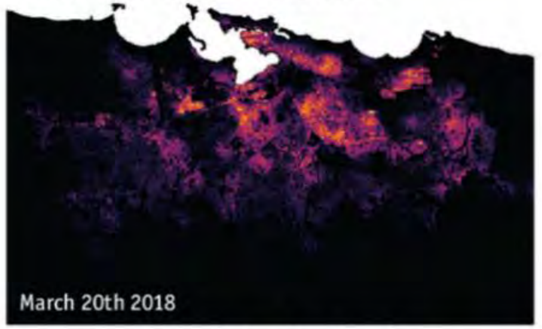



**Before Hurricane Maria makes landfall**




**Immediate aftermath of Hurricane Maria**

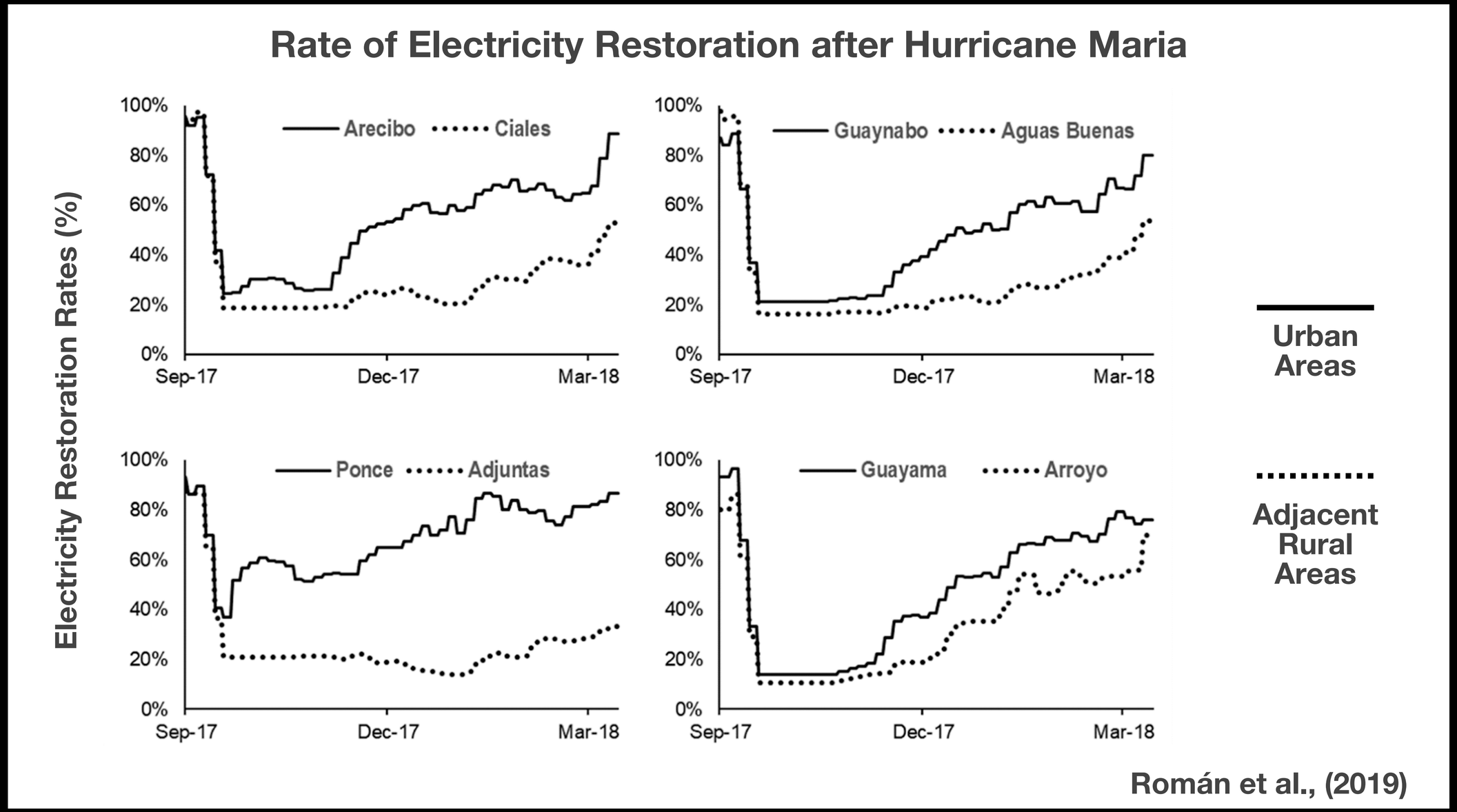

**Six months after Hurricane Maria**




Source: Suomi NPP VIIRS data from Miguel Román, NASA Disasters Programme

# Food Nutrition vs Food Safety...

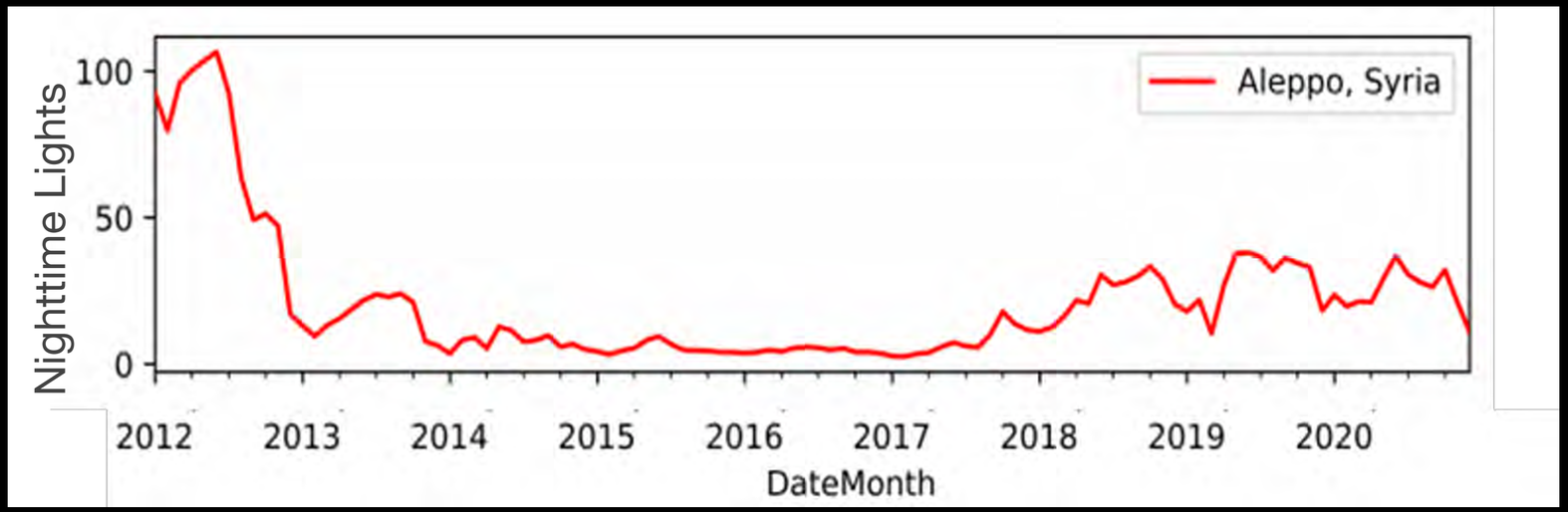
# Maria's Dilemma…



# Aleppo’s Dilemma…

# Aleppo, Syria

Preparations War Post-War



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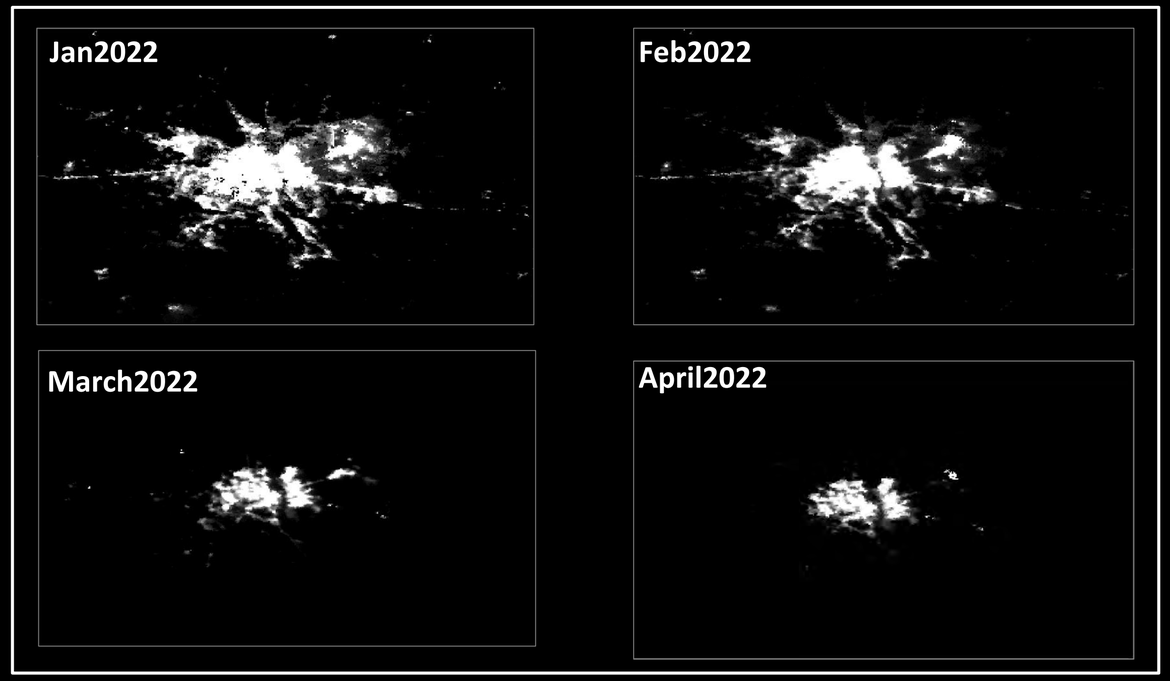
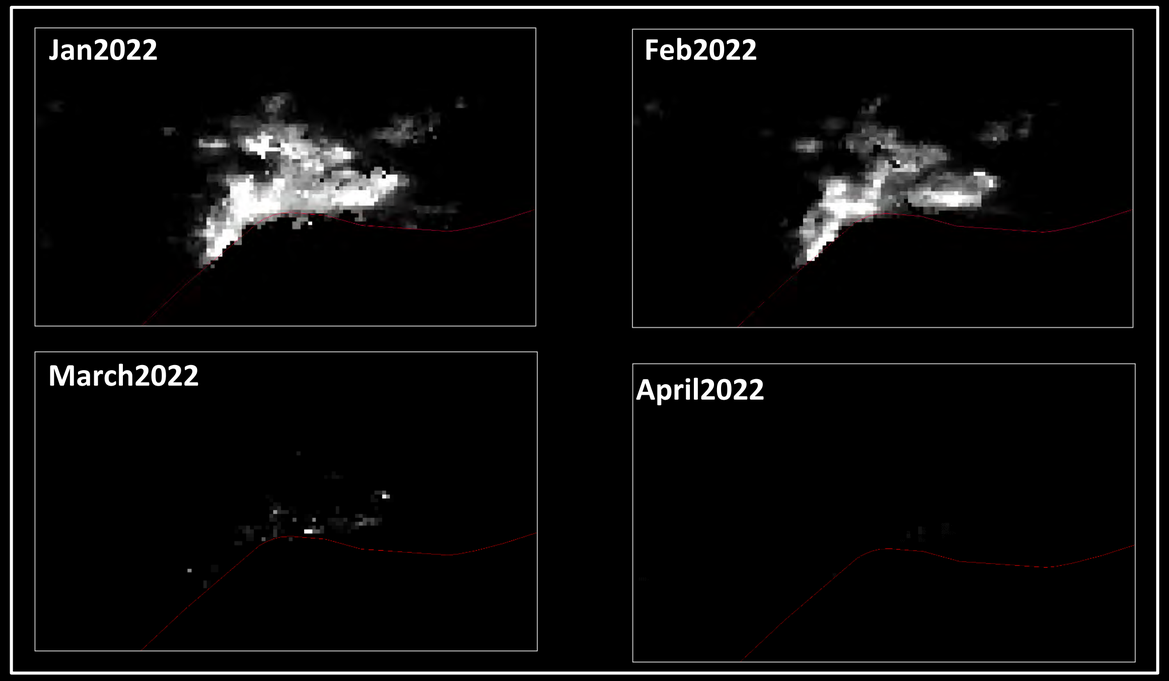
## Kiev




## Mariupol




https://blackmarble.gsfc.nasa.gov/

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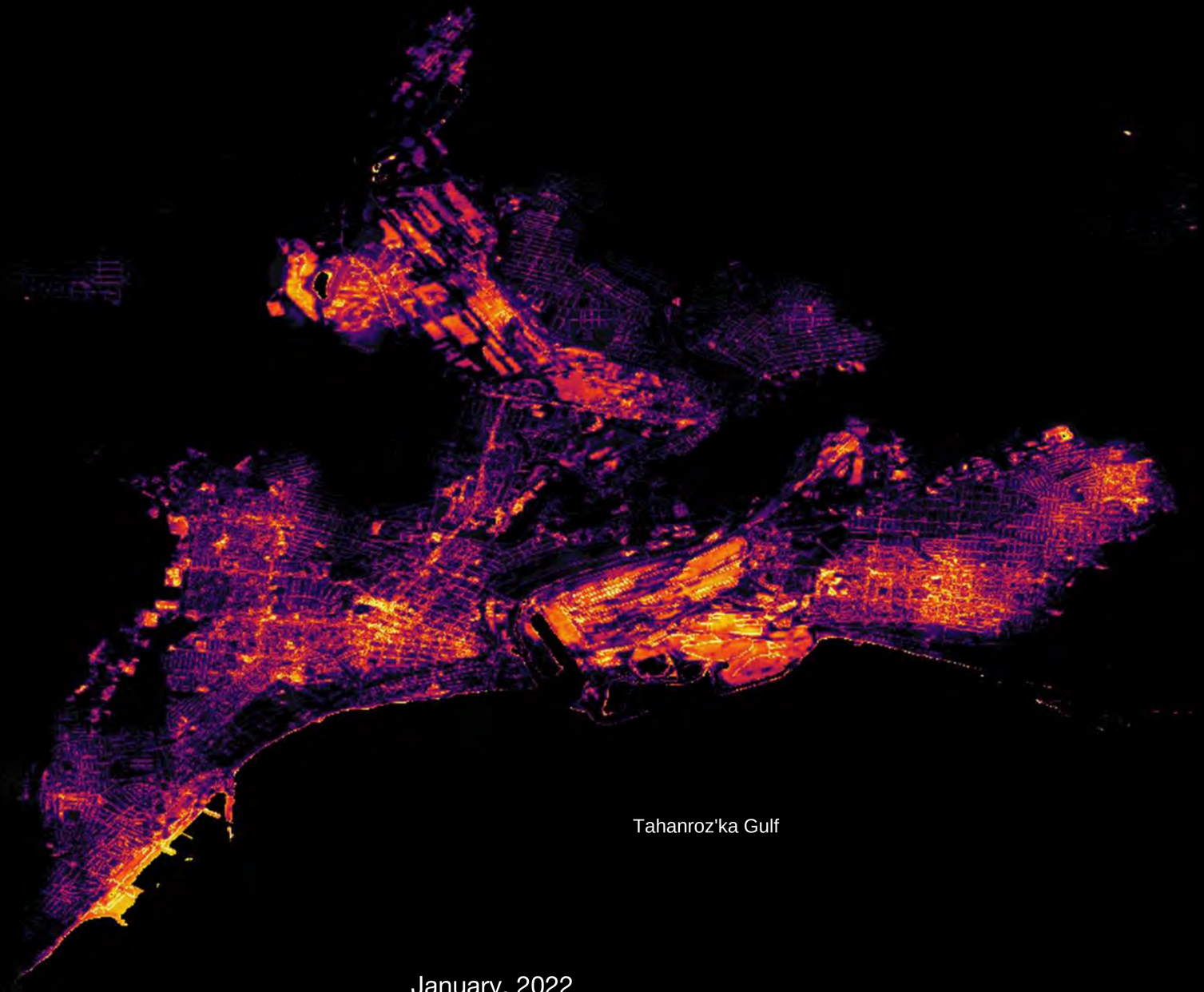
# Mariupol, Ukraine

https://blackmarble.gsfc.nasa.gov/




January, 2022

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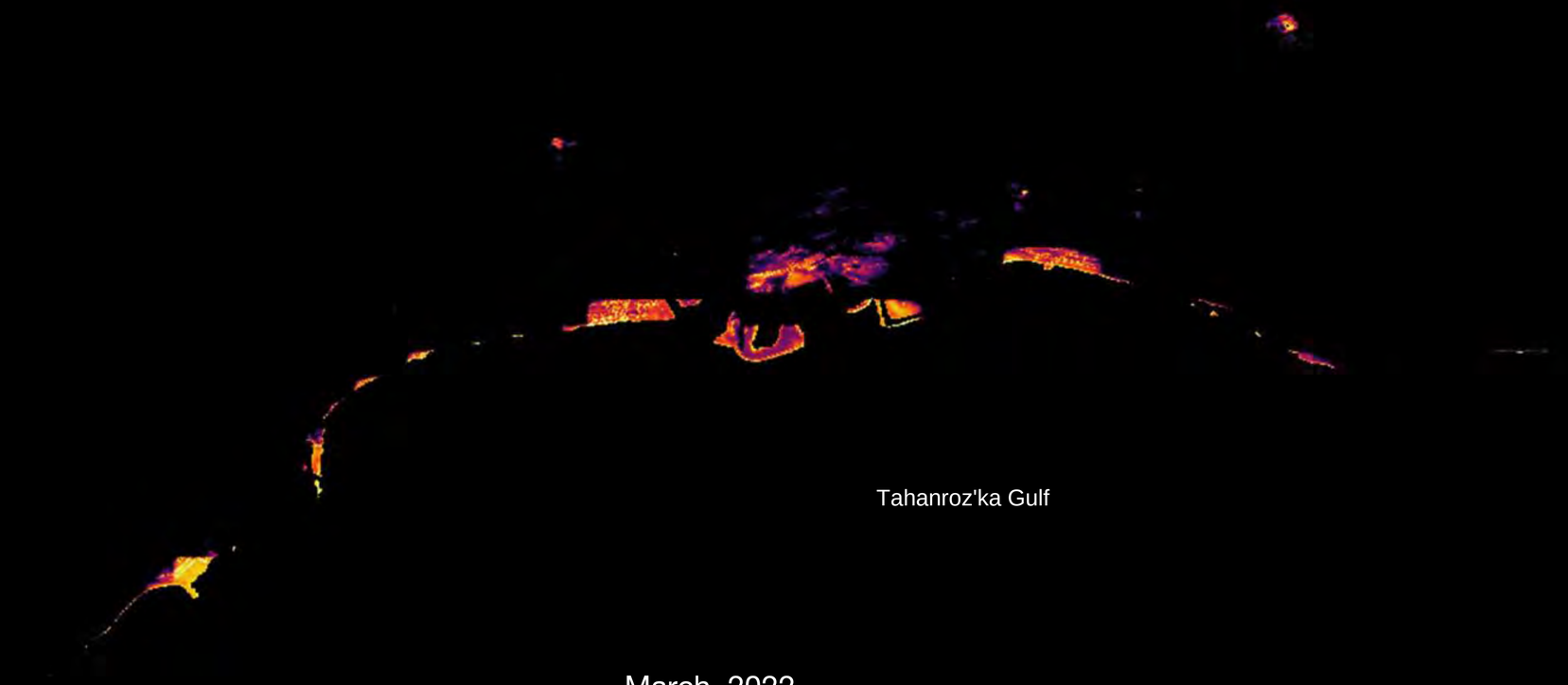
Mariupol, Ukraine

https://blackmarble.gsfc.nasa.gov/




March, 2022

# Part II Implications for Sustainability and the Ukraine Conflict

- When critical resources are used as pawns, sustainability collapses and human suffering accelerates.
- The linkages between food security and electricity are significant.
- Sustainability science has to be spatially disaggregated and include “the last mile”.
- ‘Big Data’ and analytical tools are vital instruments of human understanding, accountability, and transparency.