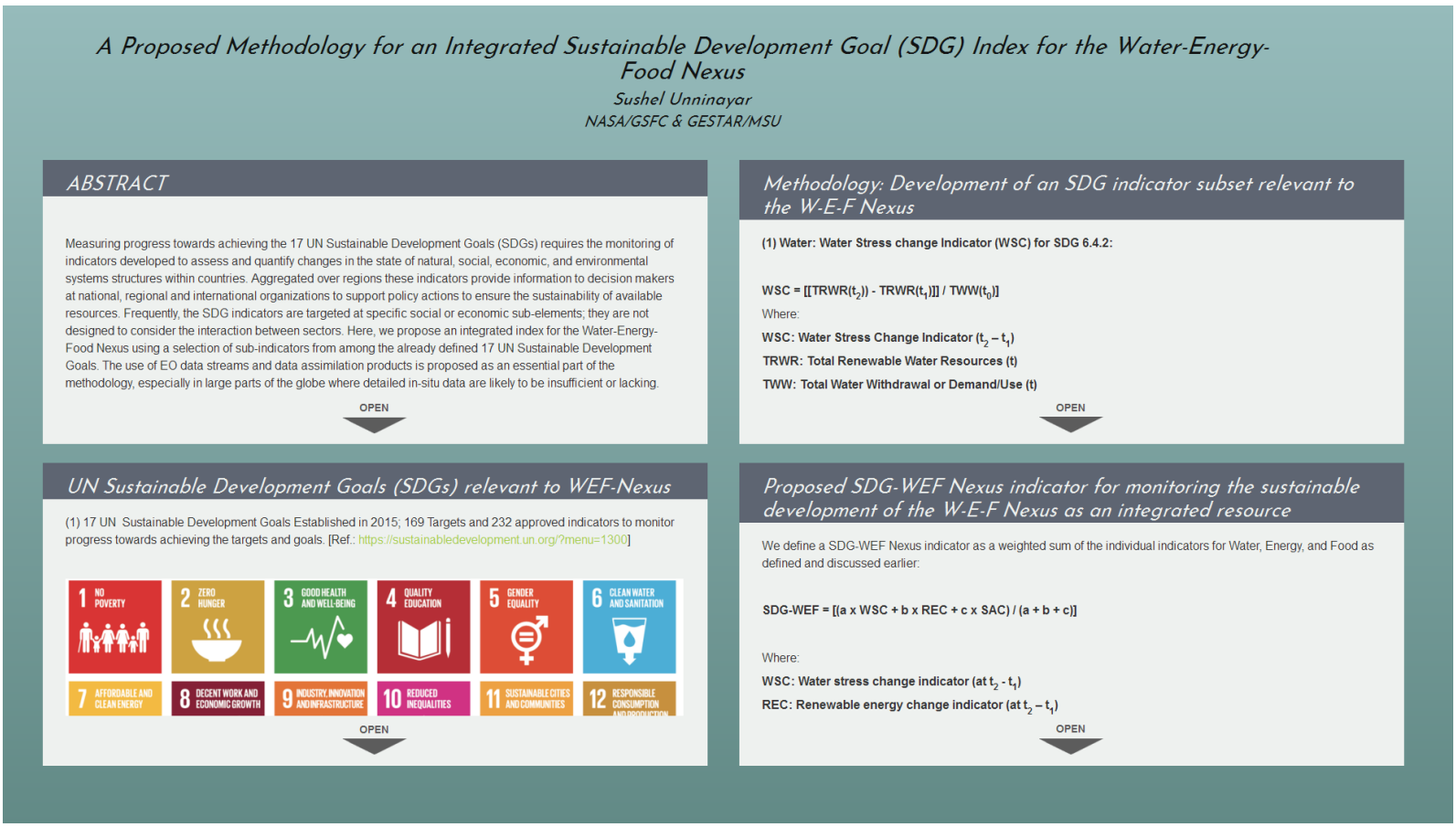
A Proposed Methodology for an Integrated Sustainable Development Goal (SDG) Index for the Water-Energy-Food Nexus



A Proposed Methodology for an Integrated Sustainable Development Goal (SDG) Index for the Water-Energy-Food Nexus

Sushel Unninayar

NASA/GSFC & GESTAR/MSU

ABSTRACT

Measuring progress towards achieving the 17 UN Sustainable Development Goals (SDGs) requires the monitoring of indicators developed to assess and quantify changes in the state of natural, social, economic, and environmental systems structures within countries. Aggregated over regions these indicators provide information to decision makers at national, regional and international organizations to support policy actions to ensure the sustainability of available resources. Frequently, the SDG indicators are targeted at specific social or economic sub-elements; they are not designed to consider the interaction between sectors. Here, we propose an integrated index for the Water-Energy-Food Nexus using a selection of sub-indicators from among the already defined 17 UN Sustainable Development Goals. The use of EO data streams and data assimilation products is proposed as an essential part of the methodology, especially in large parts of the globe where detailed in-situ data are likely to be insufficient or lacking.

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Methodology: Development of an SDG indicator subset relevant to the W-E-F Nexus

(1) Water: Water Stress change Indicator (WSC) for SDG 6.4.2:

WSC = [[TRWR(t_2)) - TRWR(t_1)]] / TWW(t_0)]

Where:

WSC: Water Stress Change Indicator ($t_2 - t_1$)

TRWR: Total Renewable Water Resources (t)

TWW: Total Water Withdrawal or Demand/Use (t)

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UN Sustainable Development Goals (SDGs) relevant to WEF-Nexus

(1) 17 UN Sustainable Development Goals Established in 2015; 169 Targets and 232 approved indicators to monitor progress towards achieving the targets and goals. [Ref.: https://sustainabledevelopment.un.org/?menu=1300]

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

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Proposed SDG-WEF Nexus indicator for monitoring the sustainable development of the W-E-F Nexus as an integrated resource

We define a SDG-WEF Nexus indicator as a weighted sum of the individual indicators for Water, Energy, and Food as defined and discussed earlier:

SDG-WEF = [(a x WSC + b x REC + c x SAC) / (a + b + c)]

Where:

WSC: Water stress change indicator (at t_2 - t_1)

REC: Renewable energy change indicator (at $t_2 - t_1$)

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Sushel Unninayar

NASA/GSFC & GESTAR/MSU

PRESENTED AT:

ABSTRACT

Measuring progress towards achieving the 17 UN Sustainable Development Goals (SDGs) requires the monitoring of indicators developed to assess and quantify changes in the state of natural, social, economic, and environmental systems structures within countries. Aggregated over regions these indicators provide information to decision makers at national, regional and international organizations to support policy actions to ensure the sustainability of available resources. Frequently, the SDG indicators are targeted at specific social or economic sub-elements; they are not designed to consider the interaction between sectors. Here, we propose an integrated index for the Water-Energy-Food Nexus using a selection of sub-indicators from among the already defined 17 UN Sustainable Development Goals. The use of EO data streams and data assimilation products is proposed as an essential part of the methodology, especially in large parts of the globe where detailed in-situ data are likely to be insufficient or lacking. Once the methodology is validated and tested in a selection of pilot regions, it can be made available to all interested national, regional and international development organizations and programs.

Primary Goal: EO/RS WEF-SDG Index to monitor sustainability of natural resources and socio-economic activity.

UN SUSTAINABLE DEVELOPMENT GOALS (SDGS) RELEVANT TO WEF-NEXUS

(1) 17 UN Sustainable Development Goals Established in 2015; 169 Targets and 232 approved indicators to monitor progress towards achieving the targets and goals.
[Ref.: https://sustainabledevelopment.un.org/?menu=1300 (https://sustainabledevelopment.un.org/?menu=1300)]

[Ref.: UN Sustainable Development Goals Knowledge Platform: https://sustainabledevelopment.un.org/?menu=1300 (https://sustainabledevelopment.un.org/?menu=1300)]

- EOs are relevant for many policy level decisions aimed at the sustainable development of the environment, natural resources, and socio-economic human activity.
- For the purposes of the Water-Energy-Food Nexus, we choose a subset of the 17 SDG's to formulate a complex WEF Index.

We chose the following SDGs:

(1) SDG 6--Water related: Goal: Ensure availability and sustainable management of water and sanitation for all

Target 6.4: By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.

Indicator 6.4.2: Level of water stress: freshwater withdrawal as a proportion of available freshwater resources.

Custodial agency: FAO (http://www.fao.org/sustainable-development-goals/en/). Custodial agency for fresh water extent and quality: UNE (https://www.unenvironment.org/explore-topics/sustainable-development-goals). [Ref.: https://unstats.un.org/sdgs/metadata/]

- Low level of water stress: combined withdrawal by all sectors is marginal relative to available total renewable freshwater resources

- High level of water stress: Combined withdrawal by all sectors is substantial fraction of total renewable freshwater resources with potentially larger impacts on the sustainability of the resource and potential of conflicts and competition between users.

(2) SDG 7--Energy related: Goal: Ensure access to affordable, reliable, sustainable and modern energy for all

Target 7.2: By 2030, increase substantially the share of renewable energy in the global energy mix

Indicator 7.2.1: Renewable energy share in the total final energy consumption.

Custodial agencies: International Energy Agency (IEA), United Nations Statistical Division (UNSD-DESA, International Renewable Energy Agency (IRENA).
References: https://unstats.un.org/sdgs/metadata/; https://www.iea.org/

Renewable energy consumption includes consumption of energy derived from: hydro, solid biofuels, wind, solar, liquid biofuels, biogas, geothermal, marine and waste. Total final energy consumption is calculated from national balances and statistics as total final consumption minus non-energy use.

(3) SDG 2--Food related: Goal: End hunger, achieve food security and improved nutrition and promote sustainable agriculture

Target 2.4: By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality

Indicator 2.4.1: Proportion of agricultural area under productive and sustainable agriculture.
Custodial agency: FAO.
References: https://unstats.un.org/sdgs/metadata/; http://www.fao.org/3/CA2639EN/ca2639en.p

The focus is on agricultural and livestock production--excluding forestry, fisheries, and aquaculture. Dimensions to be covered include environmental, economic, and social dimensions in the sustainability assessment. Scale: farm level aggregated to higher levels. Themes include: land productivity, profitability, resilience, soil health, water use, fertilizer pollution risk, pesticide risk, biodiversity, decent employment. Sub-indicators include: Farm output value per hectare, net farm income, risk mitigation mechanisms, prevalence of soil degradation, variations in water availability, management of fertilizers, management of pesticides, use of biodiversity friendly practices, wage rate in agriculture. The indicator assessment is reported in a dashboard with three levels of sustainability: Red: Unsustainable; Yellow: Acceptable; Green: Desirable.

Other relevant SDGs include:

(**4) Climate-- SDG 13**: Goal: Take urgent action to combat climate change and its impacts

(5) Life on Land--SDG 15 (Terrestrial ecosystems, land degradation, desertification, biodiversity): Goal: Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

(6) Urban--SDG 11: Goal: Make cities and human settlements inclusive, safe, resilient and sustainable.

METHODOLOGY: DEVELOPMENT OF AN SDG INDICATOR SUBSET RELEVANT TO THE W-E-F NEXUS

(1) Water: Water Stress change Indicator (WSC) for SDG 6.4.2:

$WSC = [[TRWR(t_2)) - TRWR(t_1)]] / TWW(t_0)]$

Where:

WSC: Water Stress Change Indicator ($t_2 - t_1$)

TRWR: Total Renewable Water Resources (t)

TWW: Total Water Withdrawal or Demand/Use (t)

t_0 = Reference or baseline time (year or average over years) --e.g., 2010 or 2010-2015

t_1 = Beginning time interval for computation of indicator. E.g., 2010

t_2 = End time period for indicator computations. E.g., 2015

Domain area = per unit area or district, country, region, transboundary, global

Data: RS Observation for TRWR change (WSC): GRACE (Gravity Anomaly and Climate Experiment twin-satellite) downscaled by data assimilation models to between 12 km to 50 km resolution. The nominal resolution for GRACE estimates of water storage is approximately 300 km - 400 km. GRACE captures change in all water components of the atmosphere-terrestrial Earth system and includes surface waters, soil moisture and shallow ground water aquifers--changes in the gravity field are fastest in the water storage terms in the Earth system and hence are well quantified. As a proxy for water storage change, surface water extent change can be derived from Landsat (30m) and MODIS (250m).

(2) Energy: Renewable Energy Change Indicator (REC) for SDG 7.2.1

For the purpose of the WEF indicator, we define a Renewable Energy Conversion/change (REC) efficiency as a ratio of the RE change to TED (total energy demand/consumption), as follows

$[REC] = [RE\ (t_2) - RE\ (t_1)]/[TED(t_0)]$

Where $RE = RE_s$ (Solar) + RE_w (Wind) + RE_h (hydro)

REC = Renewable energy conversion/change ($t_2 - t_1$)

RE = Renewable energy (t)

RE_s = Renewable solar energy (t)

RE_w = Renewable wind energy (t)

RE_h = Renewable hydro energy (t)

TED = Total energy demand/consumption (t)

t: same as defined in Water Stress Change WSC above

t_0 = Reference or baseline time (year or average over years)--e.g., 2010 or 2010-2015

t_1 = Beginning time interval for computation of indicator. E.g., 2010

t_2 = End time period for indicator computations. E.g., 2015

Domain area = per unit area or district, country, region, transboundary, global

Data: Landsat/Sentinel, Terra/Aqua-MODIS, NOAA-VIIRS, NASA-GMAO/GEOS-5 (Merra-2) solar, wind energy product. Other relevant EO/RS data sets include surface solar radiation budget components and cloud cover; near-surface winds, lakes/reservoirs capacities/extent/elevation.

(3) Food: Sustainable agricultural area change (SAC) indicator for SDG 2.4.1

Here, sustainable Agricultural area (SA) is defined as Total (potential-productive /vegetated) Agricultural area (TA) - Land Degradation Area (LDA) - Deforestation Area (DFA) – Urbanization Area (UA)

SAC = [[SA(t_2) - SA(t_1)] / TA (t_0)l]

Where SA(t) = TA(t) - LDA(t) - DFA(t) – UA(t)

SAC = Sustainable agricultural area change (t_2 – t_1)

SA = Sustainable agricultural area (t)

TA = Total (potential-productive/vegetated) agricultural area (t)

LDA = Land Degradation area (t)

DFA = Deforestation area (t)

UA = Urbanization area (t)

TA(t0) = Total (potential-productive/vegetated) agricultural area baseline for time t_0

t: same as defined in Water Stress Change WSC above

t_0 = Reference or baseline time (year or average over years)--e.g., 2010 or 2010-2015

t_1 = Beginning time interval for computation of indicator. E.g., 2010

t_2 = End time period for indicator computations. E.g., 2015

Domain area = per unit area or district, country, region, transboundary, global

Data set: Landsat/Sentinel, MODIS, VIIRS, SMAP/SMOS, GPM; NDVI and derivatives of NDVI, Land surface (Land use and land cover) characterization--LULC; Land Information Systems (LIS), Land data assimilation systems(LDAS); Soil moisture (SM) and land vegetation cover (NDVI index) for land degradation (not associated with climate change), desertification; GPM precipitation for assessments of renewable productive land areas; Digital elevation model data (DEM), Carbon budget assessments--as needed.

PROPOSED SDG-WEF NEXUS INDICATOR FOR MONITORING THE SUSTAINABLE DEVELOPMENT OF THE W-E-F NEXUS AS AN INTEGRATED RESOURCE

We define a SDG-WEF Nexus indicator as a weighted sum of the individual indicators for Water, Energy, and Food as defined and discussed earlier:

SDG-WEF = [(a x WSC + b x REC + c x SAC) / (a + b + c)]

Where:

WSC: Water stress change indicator (at t_2 - t_1)

REC: Renewable energy change indicator (at t_2 – t_1)

SAC: Sustainable agriculture change indicator (at t_2 – t_1)

Weights: Equal (1/3) or some variation of:

a: Fraction of economic value attributed to Water resources related sectors = W/GDP

b: Fraction of economic value attributed to Energy production sectors = E//GDP

c: Fraction of economic value attributed to Food production sectors = F/GDP

Expanding the equation, we get:

SDG-WEF = {{a x [(TRWR(t_2) - (TRWR(t_1)] / TWW(t_0)] + b x [(RE(t_2) - RE(t_1)] / TED(t_0)] + c x [SA(t_2) - SA(t_1)] / TA(t_0)} / (a + b + c)}

t_0 = Reference or baseline time (year or average over years) --e.g., 2010 or 2010-2015

t_1 = Beginning time interval for computation of indicator. E.g., 2010

t_2 = End time period for indicator computations. E.g., 2015

Domain area = per unit area or district, country, region, transboundary, global

Can be expressed as a range - 1.0 to +1.0 or as %

[Can be re-scaled WEF = (WEF +1) / 2 x 100% (range 0 - 100%)]

Generally:

All positive (+ve trends) = Green [X] = Desirable (increasing trends in sustainability)

All negative (-ve trends) = Red [X] = Unacceptable 9decreasing trends in sustainability)

Some +ve/-ve or low values = Yellow [X] = acceptable with caution but requiring improvement or correction in one or more WEF-SDG elements

"0" is no net change or trend. That is, the net weighted impact on the economy or environment is unchanged? Individual components will show which trend is contributing most to the overall increase or decline in sustainability.

Time scales of analysis: The calculations can be performed every 5 years where the baseline reference state is one year or a time average over 5 years. A time series with repeated assessments in 5 year time intervals will show the progress of the integrated WEF-SDG Nexus indicator. Thresholds can be established with retrospective analysis. Changes that are not accompanied by changes in environmental climate conditions would reflect impacts of resource management practices and/or policy. Change in WEF-SDG time due to environmental factors will reflect climate change impacts and whether management practices are contributing to the mitigation or exacerbation of the impacts of climate change on water, energy and food resources per region or country or the world.

ABSTRACT

Measuring progress towards achieving the 17 UN Sustainable Development Goals (SDGs) requires the monitoring of indicators developed to assess and quantify changes in the state of natural, social, economic, and environmental systems structures within countries. Aggregated over regions these indicators provide information to decision makers at national, regional and international organizations to support policy actions to ensure the sustainability of available resources. Frequently, the SDG indicators are targeted at specific social or economic sub-elements: they are not designed to consider the interaction between sectors. Here, we propose an integrated index for the Water-Energy-Food Nexus using a selection of sub-indicators from among the already defined 17 UN Sustainable Development Goals. The use of EO data streams and data assimilation products is proposed as an essential part of the methodology, especially in large parts of the globe where detailed in-situ data are likely to be insufficient or lacking. Once the methodology is validated and tested in a selection of pilot regions, it can be made available to all interested national, regional and international development organizations and programs.

REFERENCES

(1) UN Sustainable Development Goals; SDG Indicators, Metadata Repository:

https://unstats.un.org/sdgs/ (https://unstats.un.org/sdgs/)

https://unstats.un.org/sdgs/metadata/ (https://unstats.un.org/sdgs/metadata/)

(2) UN Sustainable Development Goals Knowledge Platform: https://sustainabledevelopment.un.org/?menu=1300 (https://sustainabledevelopment.un.org/?menu=1300)

(3) Food and Agricultural Organization (FAO) - SDGs

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(4) UN Environment (UNE) -SDGs: https://www.unenvironment.org/explore-topics/sustainable-development-goals (https://www.unenvironment.org/explore-topics/sustainable-development-goals)

(2) International Energy Agency

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(3) DESA-UNSD (UN Depaetment of Economic and Social Affairs-UN Statistical Division):

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