Geospatial optimization and strategic investments in solar and wind:

The case of the African continent and small island states

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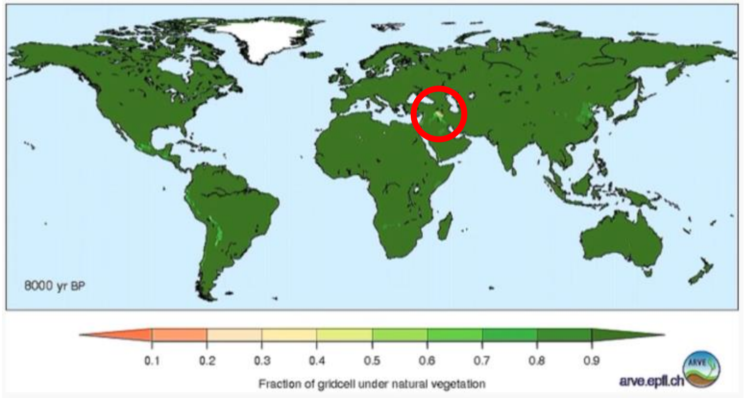
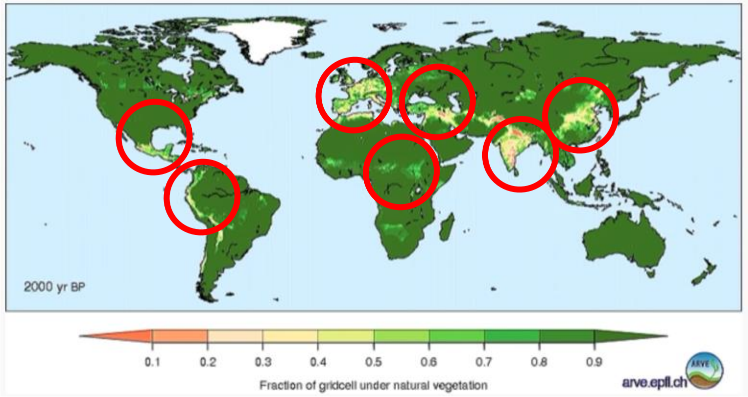
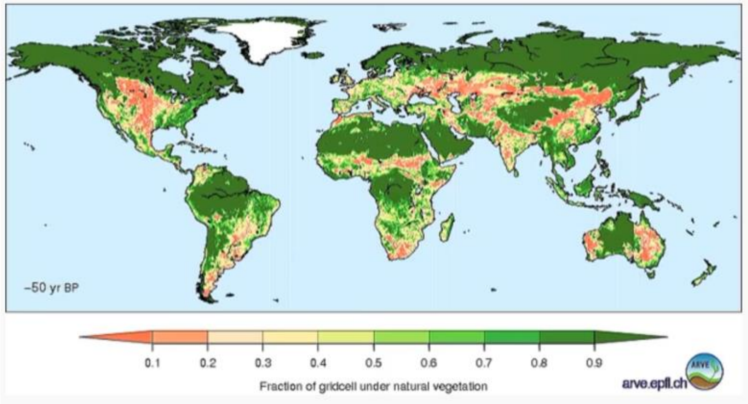
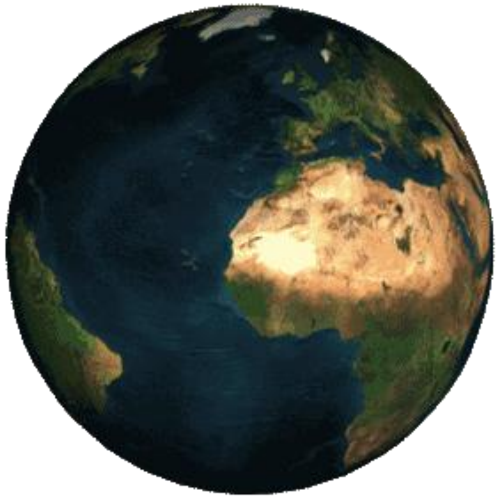
The Evolving Geospatial Context



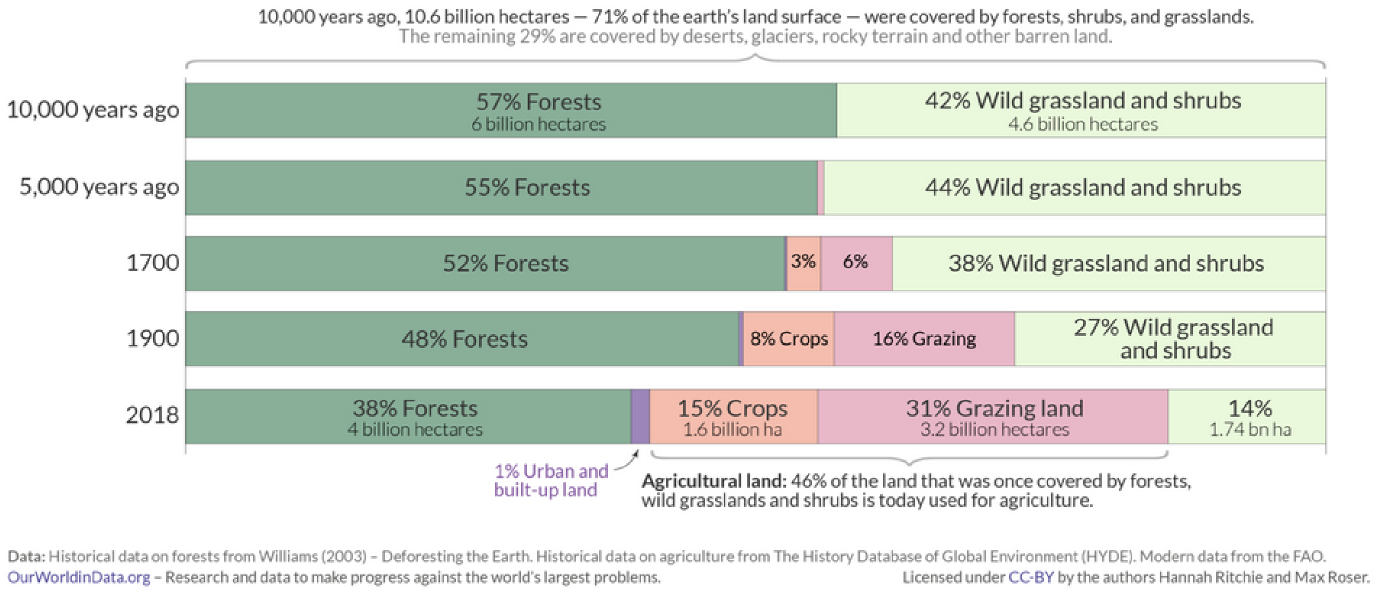




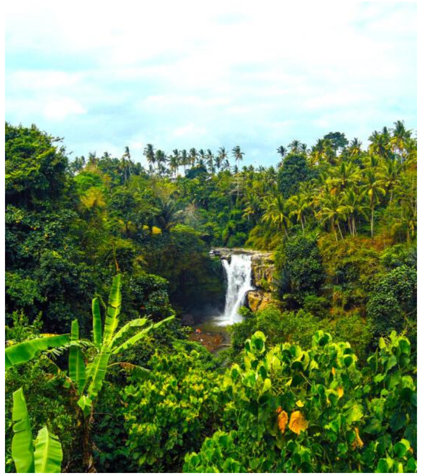


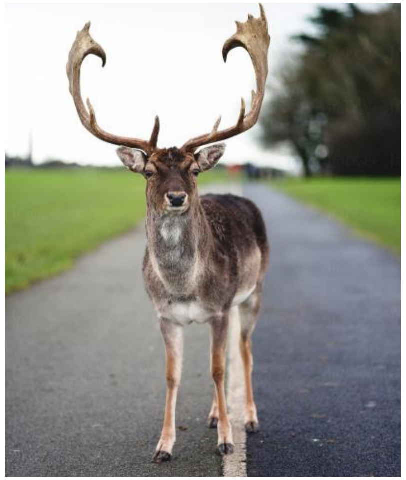
- Following the origins of agriculture (~8000 years BP), human land use has been increasing exponentially
- Beginning in Mesopotamia and in the Fertile Crescent areas of southwest Asia, intensive land use patterns developed in India; in China; in Africa; and in South/ North America some 2000 years BP
- Land use in Europe and China increased greatly following the development of cities and towns during the Middle Ages and Renaissance (500-1527)
- Prior to the industrial revolution (1750s), pre-industrial agricultural societies appropriated ~4% of the global terrestrial NPP [*Lacked the metabolic means to effectively colonize natural ecosystems*] (Malhi, 2014)
- As we raced towards modern times (1800s), settlements of the Americas and Australia by the Europeans started spreading across the continent.
- The development of the human dominated world from the onset of the industrial revolution, resulted in further exploitation of natural ecosystems [*appropriating ~34% of the global terrestrial NPP*] (Malhi, 2014)

Breakdown of Land Use Change



- About 10,000 years BP, habitable land was dominated by forests, grasslands and shrubbery
- Global population increase (603 million) around the 1700 saw an expansion of agricultural lands at the expense of forested areas, grasslands and shrubs
- In 2018, the greatest land use change was mainly due to agriculture (46%), with urban land accounting for only 1%
- About 1/3 of forests and 2/3 of grassland-shrub areas have been destroyed through agricultural land expansion
- Land resource is becoming increasingly scarce with agricultural expansion and socio-economic development
- Development projects should exploit barren lands
- The acceleration of economic globalization is impacting negatively on: (1) Global natural ecosystems; (2) Availability of land for sustainable projects (e.g Energy)





Impacts on Global Ecosystems

- Pressures on ecosystems are mainly due to agriculture, but also include mining, logging and urban sprawl
- Habitat loss not only affects species directly, but also influences the networks of ecological relationships (by altering abundance and spatial distribution of species through time)
- Habitat destruction due to high land conversion rates is regarded as the main threat to 85% of species in IUCN's Red list (WWF, 2020)

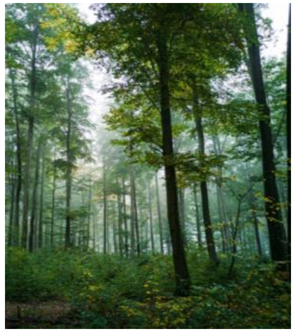
Extinct/Nearly-extinct Faunal Species due to Forest Loss

Formosan Clouded Leopard (2013)

The leopard's extinction was attributed to loss and fragmentation of lowland forests on the island of Taiwan, replaced by agriculture, forcing the cat up into ever smaller ranges at higher elevations

Spix's Macaw (2018)

Habitat loss due to agriculture and energy generation in lowland forests of Brazil drove this species to being extinct in the wild



Cryptic Treehunter (2019)

Forests became highly fragmented and converted to sugarcane plantations and pastureland in eastern Brazil, leading to habitat destruction and extinction

Extinct Floral/Faunal Species due to Wild Grassland Loss

Pensée de Cry (2011)

Habitat destruction of wild grassland due to limestone quarrying in the vicinity of French department Yonne led to the extinction of the Pensée de Cry

Acalypha dikuluwensis (2012)

Growing in the copper-rich grassland of DR Congo, this endemic flora was driven to extinction by habitat destruction due to copper mining

Xerces Blue (1941)

Fragmentation of grassland and sand dune habitat due to the growing urban development in the San Francisco Peninsula led to its extinction

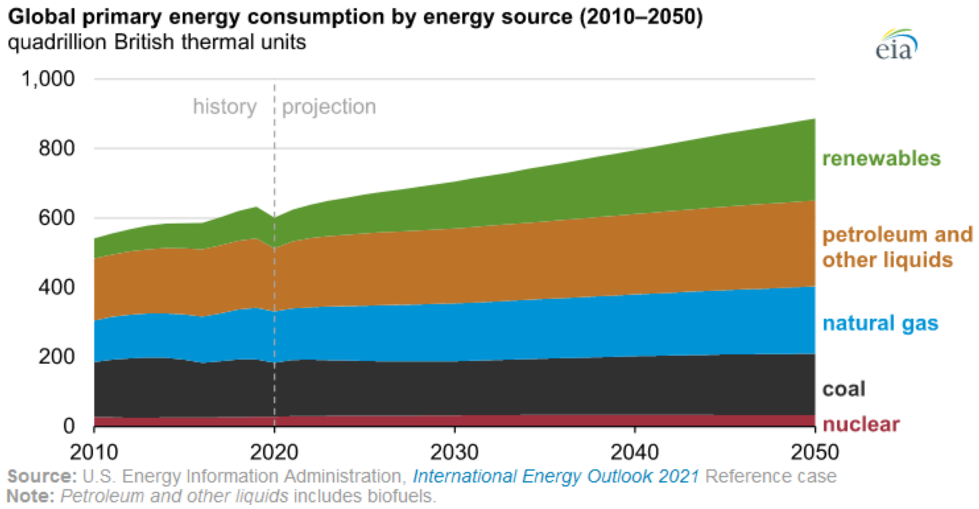
Increasing Land Requirements for RE

- Adding to the list of socio-economic pressures, is the increasing requirement of land space for RE [Decarbonize Power Systems]

- Global energy consumption is projected to increase by nearly 50% over the next 30 years with renewables growing to nearly the same level as petroleum and other liquid fuels (EIA, 2021)

- In the US, over 800,000 km² of land area will be directly impacted by energy development by 2040 (> UK + France = 786,435 km²)

- Growing renewable penetration is crucial to meet climate targets
  – *Will the expanding land use requirements for renewables impact our ability to preserve biodiversity?*



Some Historical Developments

Brimfield 6.24 MW solar farm (2013)

Solar projects accounted for ¼ of all development of natural lands in Massachusetts between 2012 and 2017 (Boston Globe, 2020)

Initially historical overlap occurs in West, but now many oriental countries are following the pace

Wakuya 25 MW Solar Power Plant (2021)

About 50 hectares of forested areas was claimed from the Miyagi Prefecture of Japan for the solar farm

3,128 RE facilities which are degrading 886 protected areas, 749 Key Biodiversity Areas, and 40 wilderness areas (Rehbein et al., 2020)

Other issues impacting on RE investments

Political Instability

An economically viable project, the Inga 3 hydropower plant, faced several development obstructions attributed to the politically unstable situation in the DR Congo.

Policy Landscape

The establishment of an appropriate legal and financial system to enhance market rule and reduce the associated risk of foreign investments should improve RE investments.

Climate Conditions

Investment in RE hotspots would generate a higher yield per unit area, maximizing on profitability and minimizing on land use requirements.

Institutional Capacity

Working in an environment where there is an established supply chain or where local contractors have the relevant expertise to carry the work forward, result in cost effective and swift projects

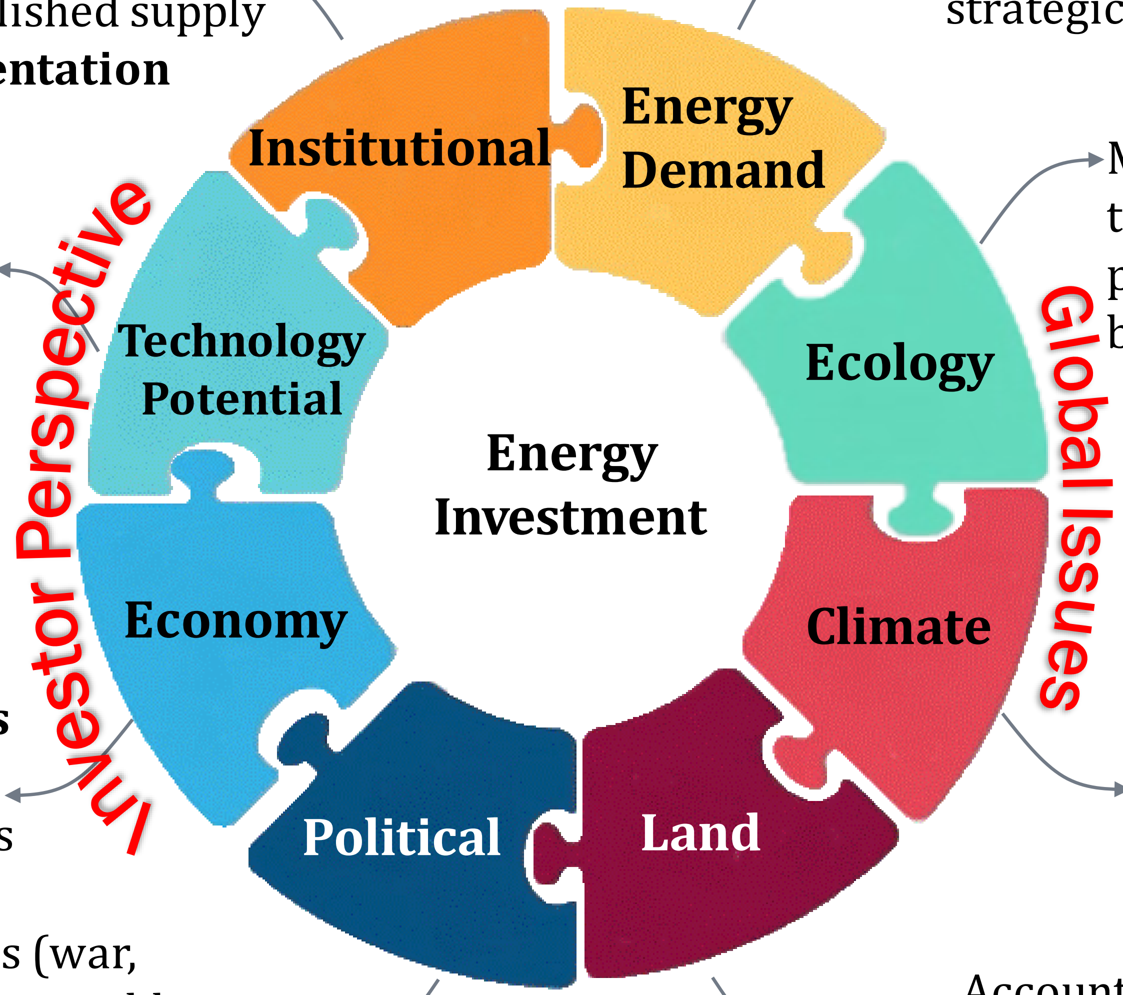
A Multi-Criterial Problem

Have an experienced and adequately trained personnel, with an established supply chain for **swift project implementation**

The adequate natural resources and geotechnical conditions for **efficient** implementation and operation of RE technologies

Account for factors that seek to reduce **capital investment costs** whilst offering conducive policy landscapes to attract investments

Investors rank **political** concerns (war, civil disturbance, corruption and unstable political situations) as a major factor influencing investments (Asiedu, 2006).



Cater for the increasing **energy demand** equitably and sustainably through strategic RE projects implementations

Minimize pressures on **biodiversity** through less overlapping of RE projects with protected areas, key biodiversity areas, and wilderness

Objective is to achieve **net-zero** emissions by 2050 – Need to achieve rapid decarbonization of Global Power Sector

Account for the **limited land resources**, being shared with socio-economic needs due to food industry and urban expansion

The Case of Africa

The African Energy Context

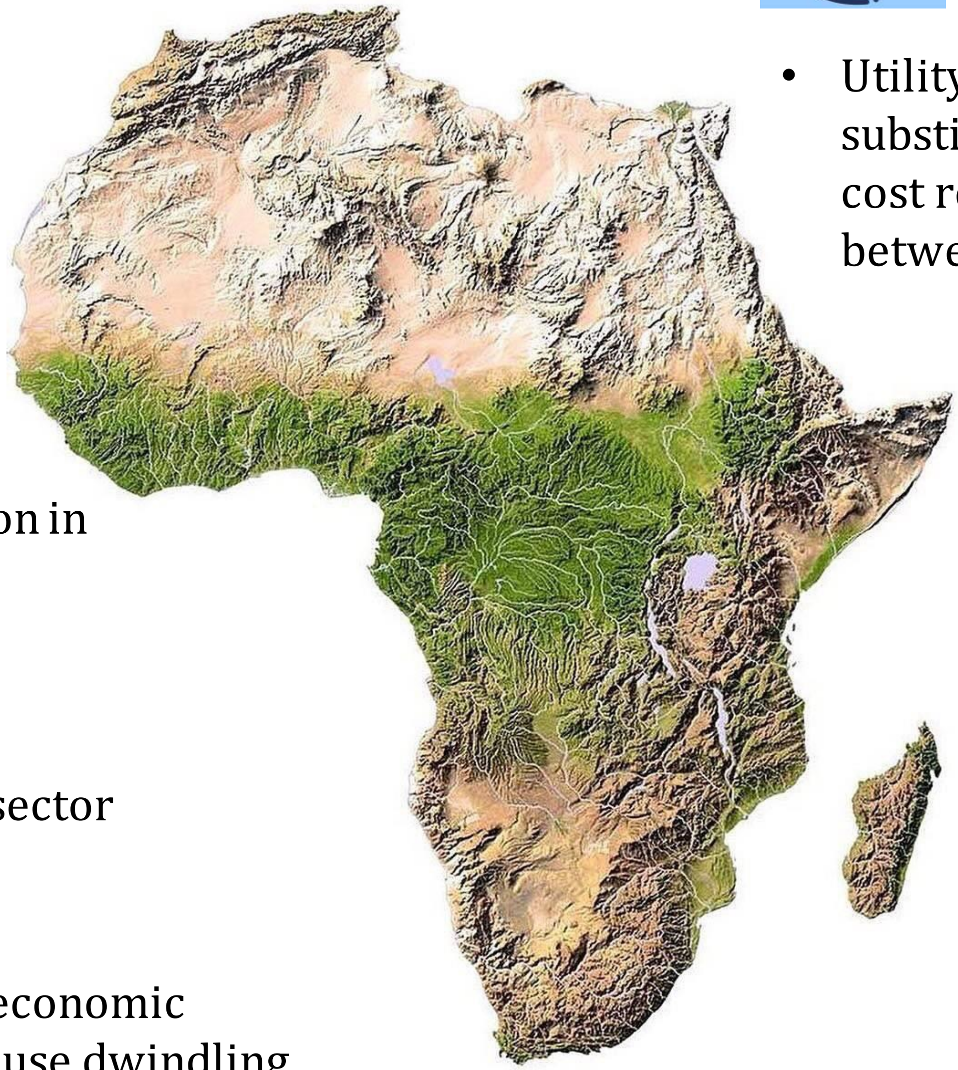
- African population expected to double by 2050 (~2.4 billion)

- Fast growing population + rate of urbanization = Threat to future climate

- Lion's share of electricity generation in Africa comes from FF (~79% centralized electricity grid)

- Important that the African power sector transitions away from a FF lock-in

- Over-reliance on FF imports have economic repercussions whilst FF exports cause dwindling revenues, resulting in fiscal pressures



- Utility-scale solar/wind are viable substitutes to FF-derived electricity with cost reductions of 69% solar and 18% wind between 2010-2016 (IRENA, 2017)

- Grid extension and densification represents the most cost-effective way of supplying electricity to 45% of population by 2030 (IEA, 2019)

- We will be exploring the potential for utility-scale, grid-connected solar PV and wind for strategic energy investments in Africa

The Investment Landscape

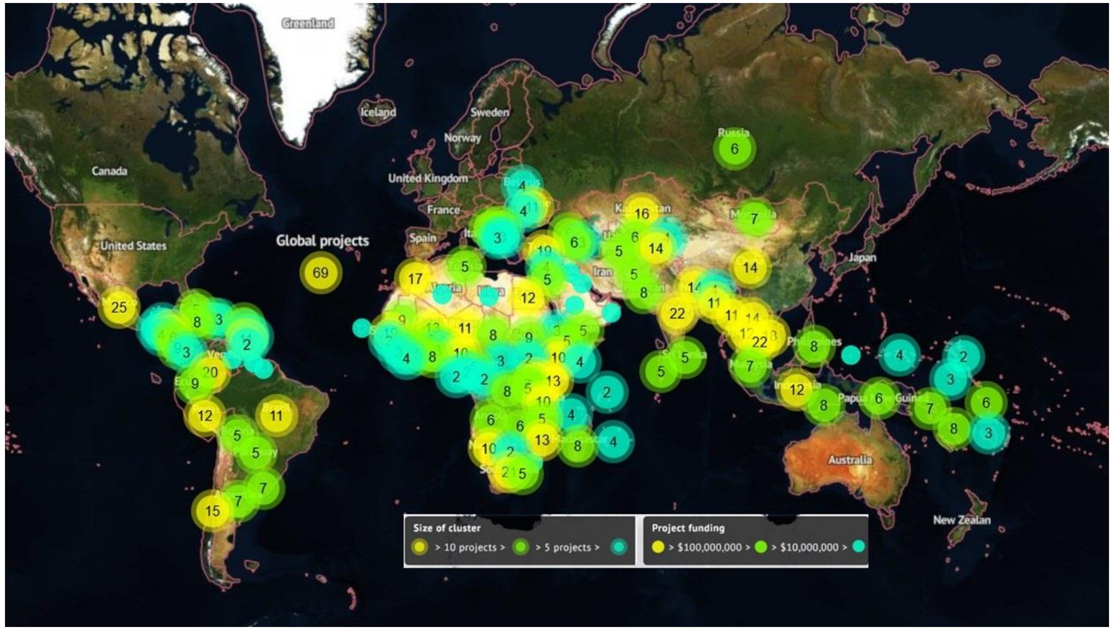
- Energy investments in Africa (2005-2015) come from:

  (1) World Bank ~ $17.6 billion mainly in FF in SSA

  (2) EU ~$16.8 billion mainly in RE in North Africa

  (3) AfDB ~$14.4 billion mainly in distribution infrastructures

  (4) Other players – including the United States, China, the Climate Investment Funds, the Arab Fund for Economic and Social Development, and the OPEC Fund for International Development (OFID) played a far smaller role.



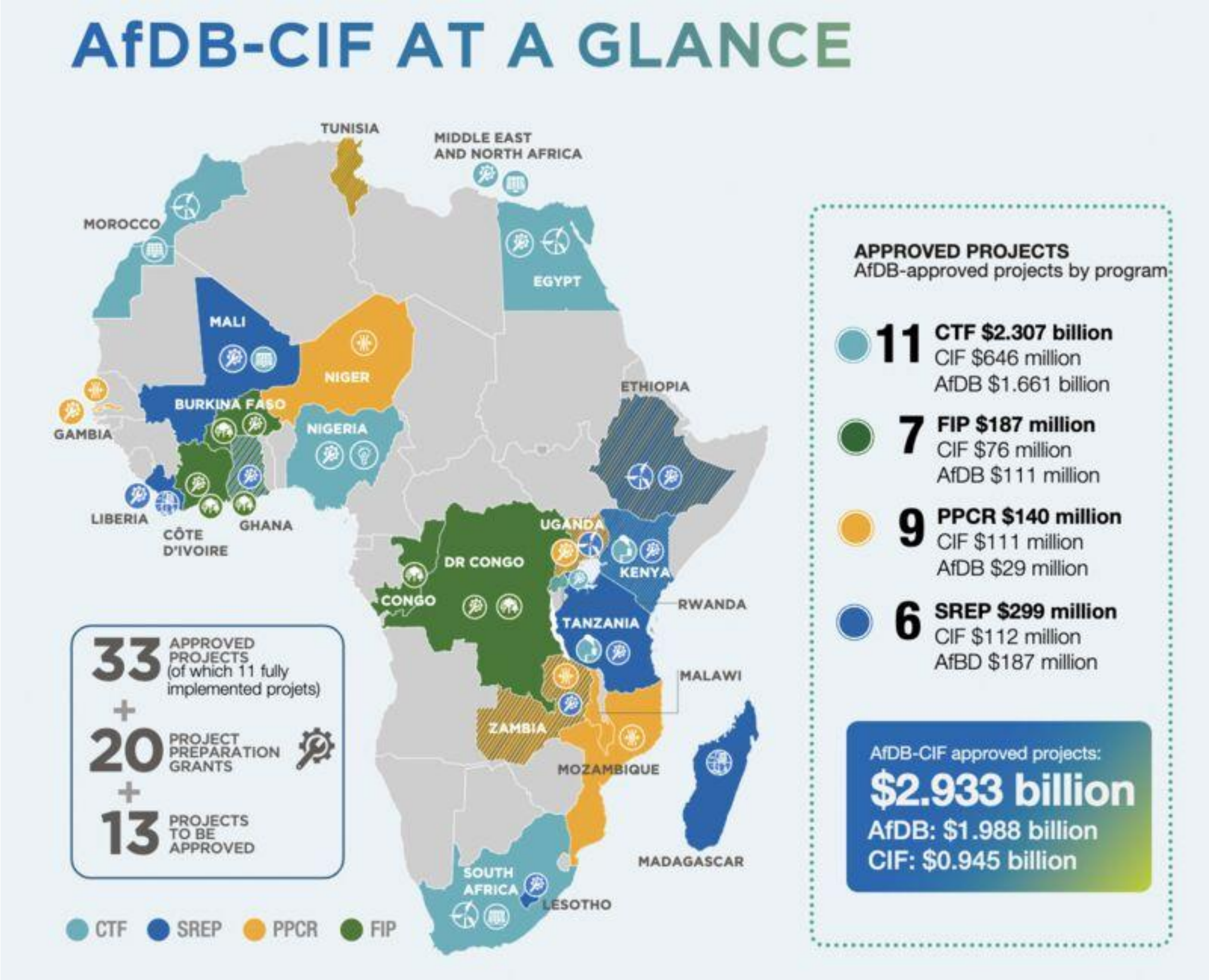
- African Progress Panel (2015) posits that excessive fragmentation +poor coordination = inefficient investments in the African power sector

Need for strategic investments in RE across the African continent

- Rolling blackouts caused by ageing coal power plants in South Africa
- Diminishing gas reserves in North Africa
- Poor energy infrastructures in Sub-Saharan Africa

Investments by AfDB - CIF

- AfDB is an Implementing Entity of the CIF and supported the development of 39 investment plans across 27 African countries with the objective of unlocking climate action.



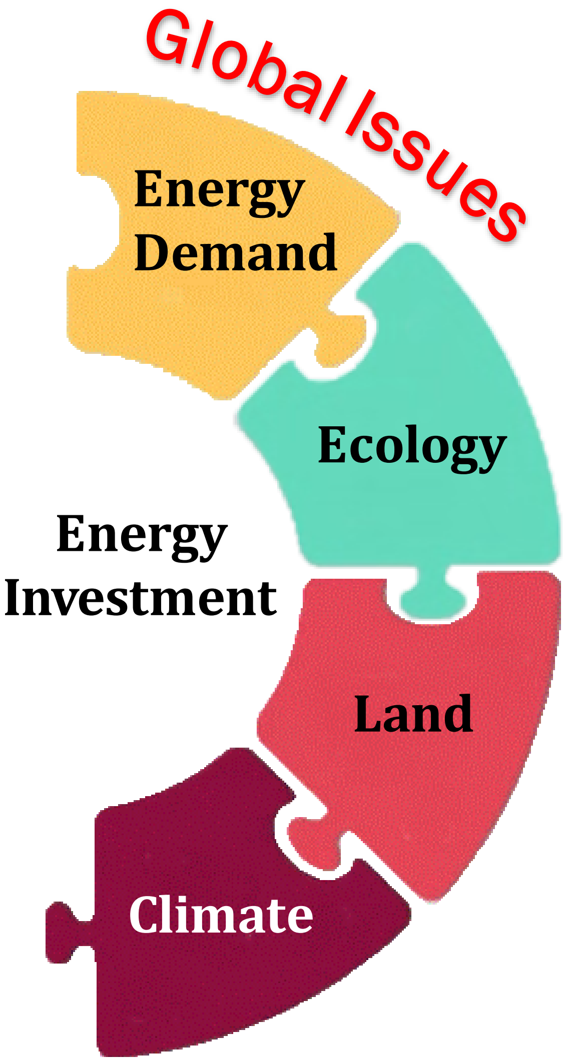
- The AfDB has approved a total of 33 projects ($945 million in CIF resources + $1,988 million of its own co-financing)

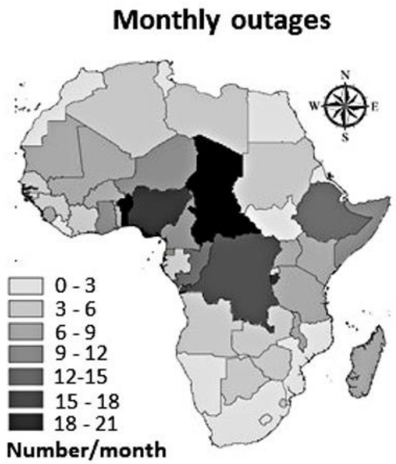
- 2 of its key programmes are:
  - **Clean Technology Fund (CTF):** Financing the deployment and transfer of low-carbon technologies with significant potential for long-term GHG emissions savings in emerging economies

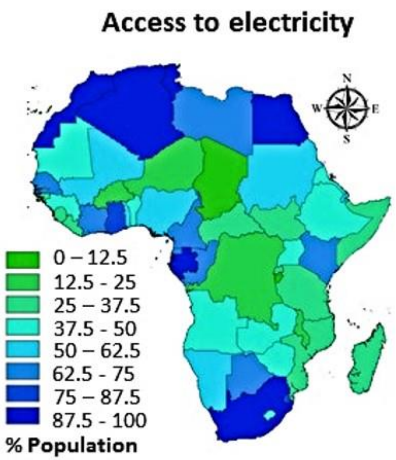
  - **Scaling Up Renewable Energy Program in Low Income Countries (SREP):** Deployment of renewable energy solutions and expand renewable energy markets in the world's poorest countries

Are these the optimum sites for investments to support both programmes from a climate action perspective?

Applying the Multi-Criteria Framework

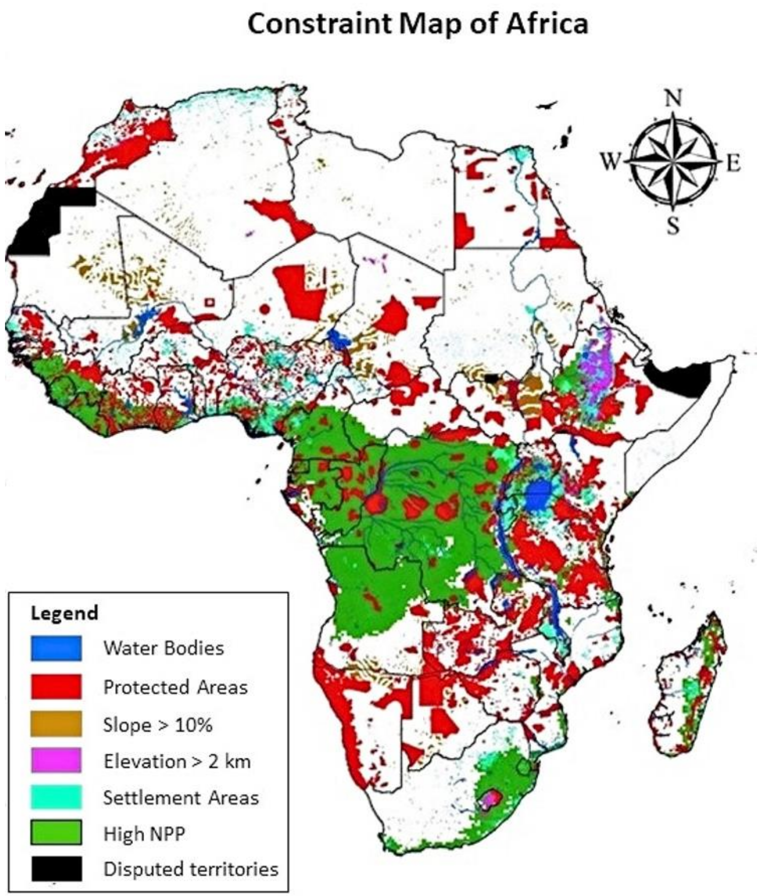




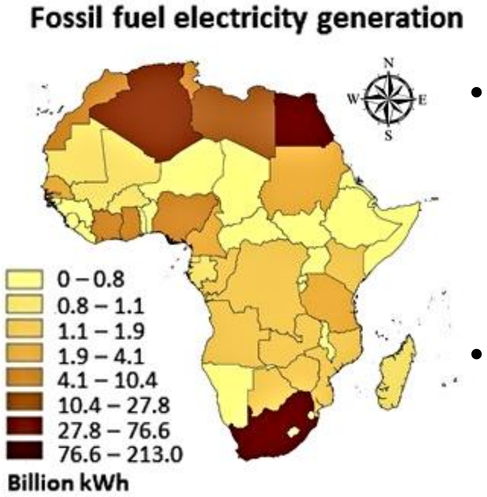


Energy demand perspectives:

- Investors motivated in improving the electricity situation of a country
- Investors seeking financial assurance for their project investments (aim at countries having reliable grid infrastructure)



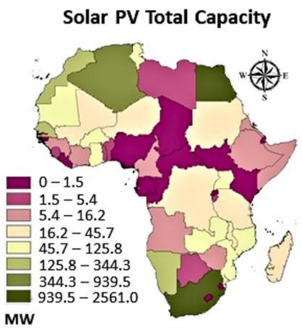
- Both protected areas and regions of high NPP are excluded from the current analysis
- Other socio-economic and technical land constraints (settlement areas, unfeasible land slopes,…) are removed

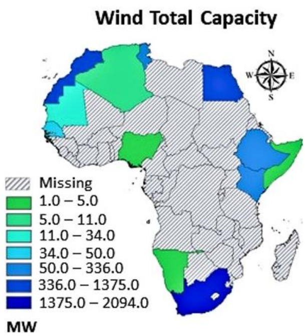


- For effective decarbonization, countries that are heavily reliant on fossil-fuel electricity should be targeted
- The strategy is to foster diversification of the energy mix towards RE implementation

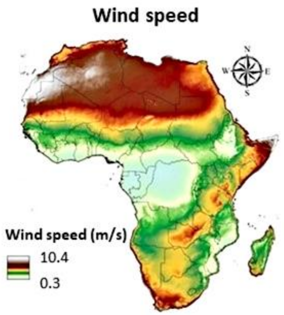
- The solar PV/onshore wind total capacity of a country is used as proxy for the institutional capacity pertaining to solar and wind farm constructions.

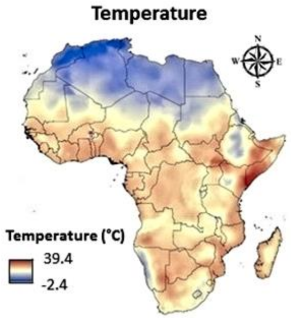
- Countries with high installed capacity would have developed the necessary expertise and established the supply chain

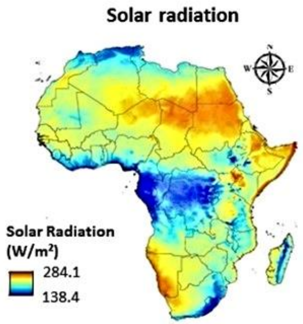




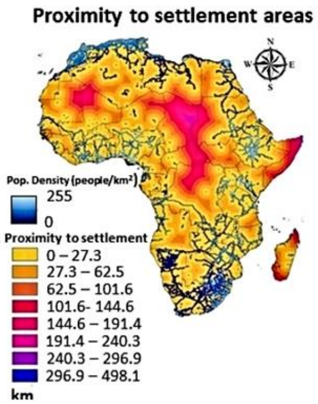
- To optimize energy harness and exploit the technology potential, climatic parameters were factored in

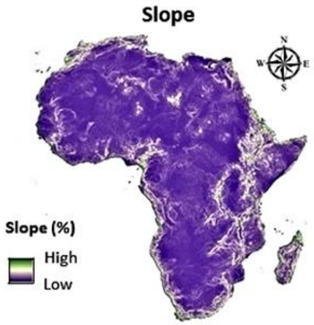


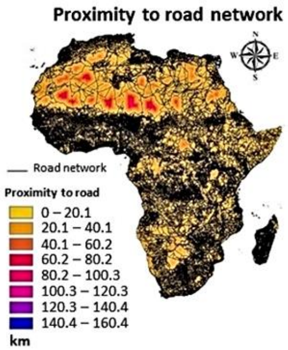


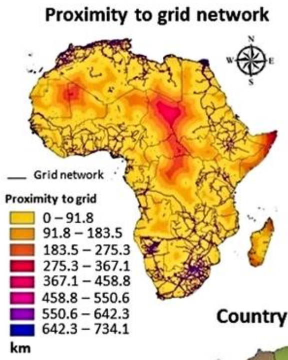


- Minimization of capital cost of investments would be achieved from using existing infrastructures and suitable slopes



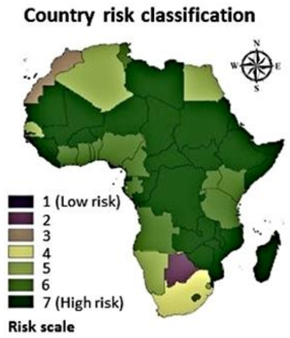


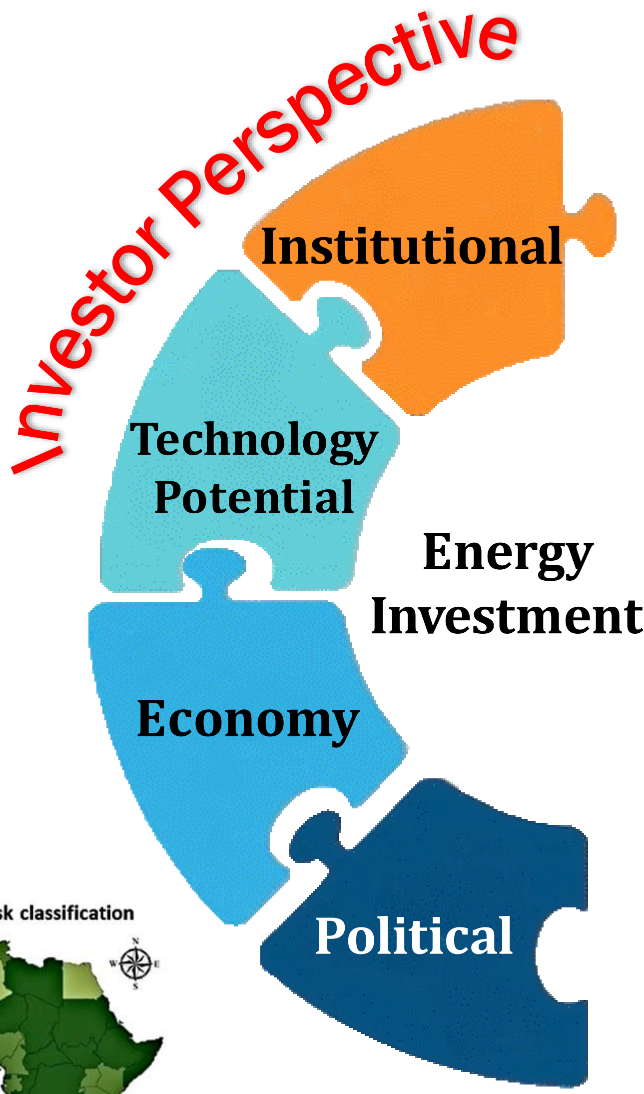




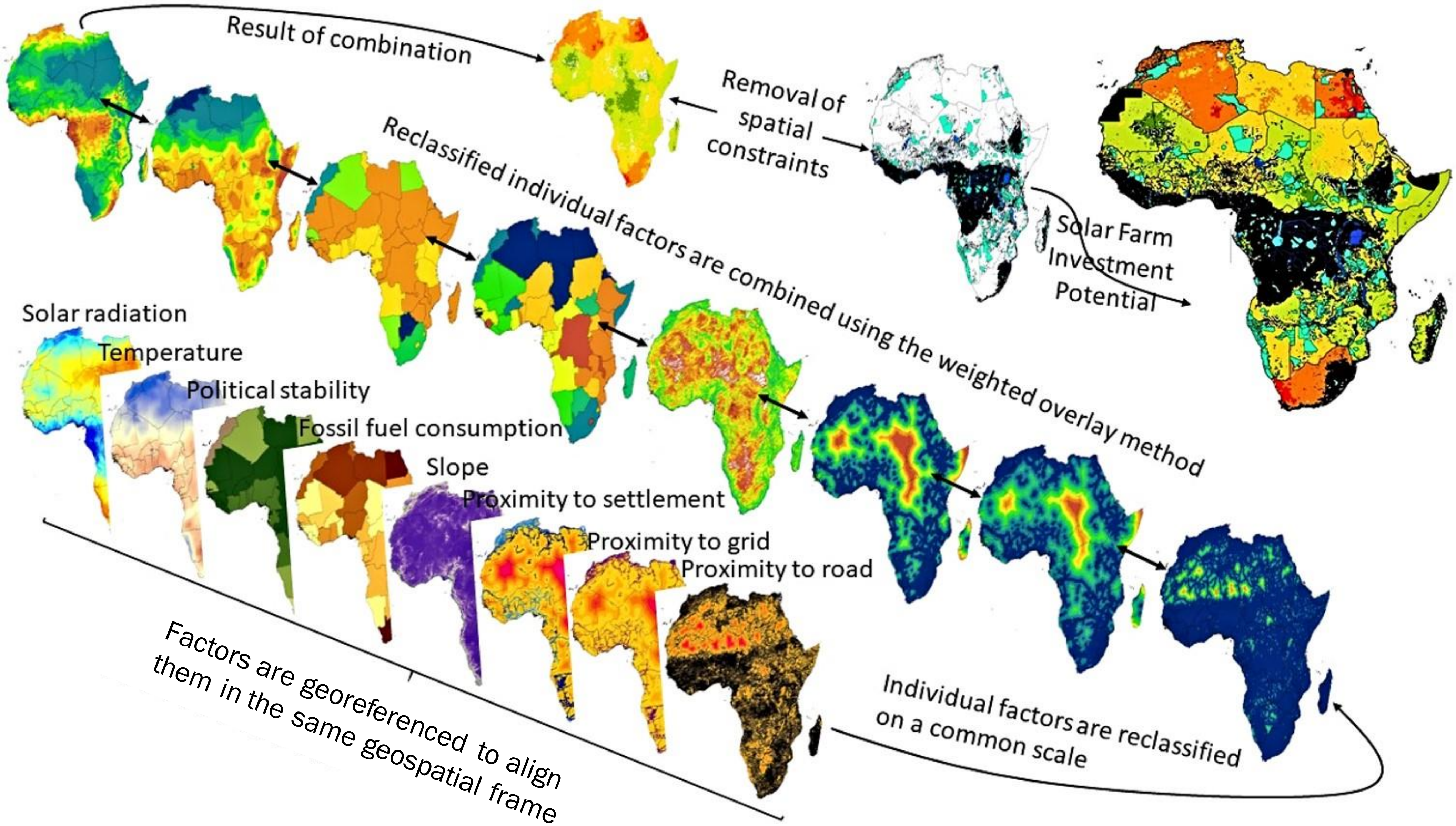
- Excluded disputed territories (Western Sahara and Somaliland)

- The OECD's country risk classification is used as a proxy for political stability and suitable investment setting. [*It captures risk associated with the investment structure in place, as well as war, civil disturbance, flood and earthquake*].



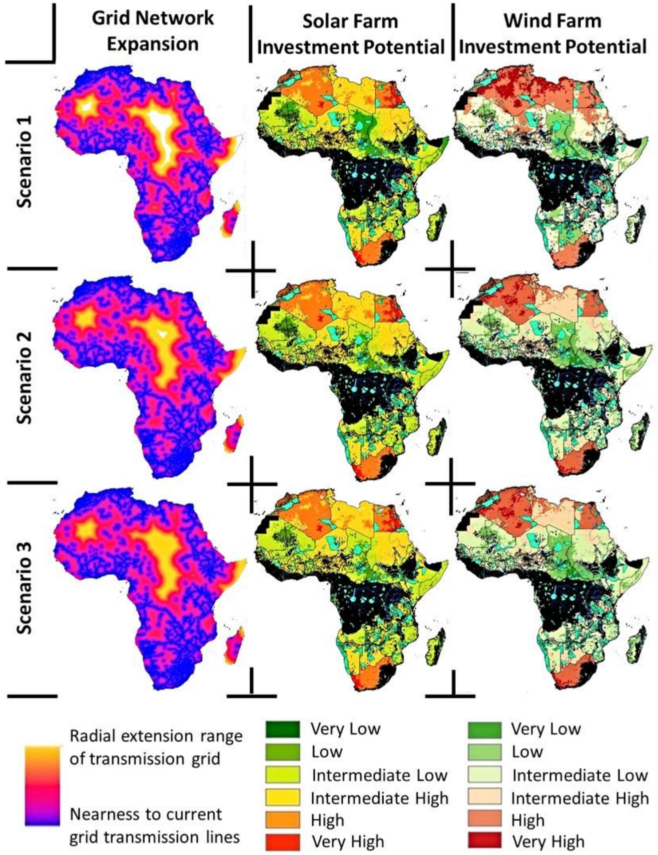


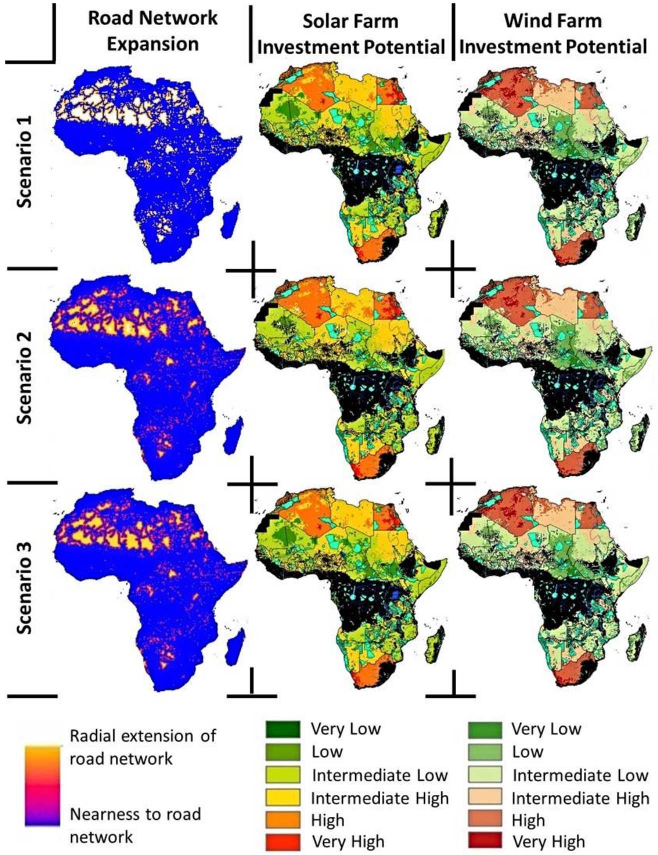
The MCDA Process

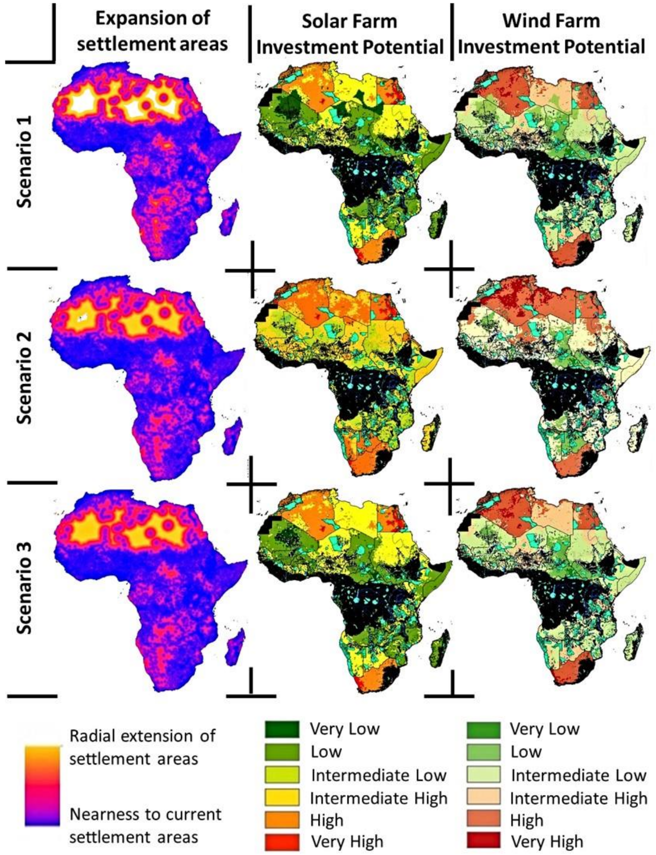


Sensitivity Analysis

Owing to the underlying uncertainties in the formulation of the model, the socio-economic parameters were varied to observe the response on spatial scales



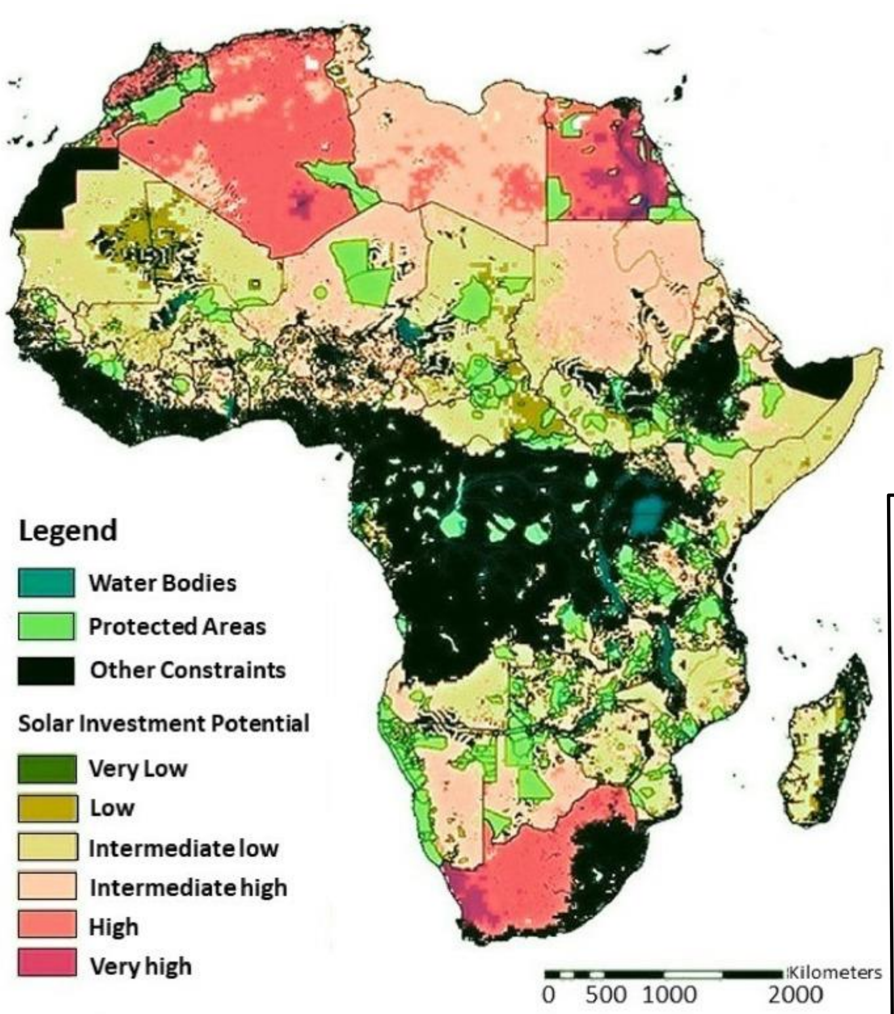




No significant change observed on geospatial scales, indicative of a robustly built model

Solar and Wind Potentials – Financial Investor Perspective

Perspective of investors seeking financial assurance for their project investments (Technical Potential)

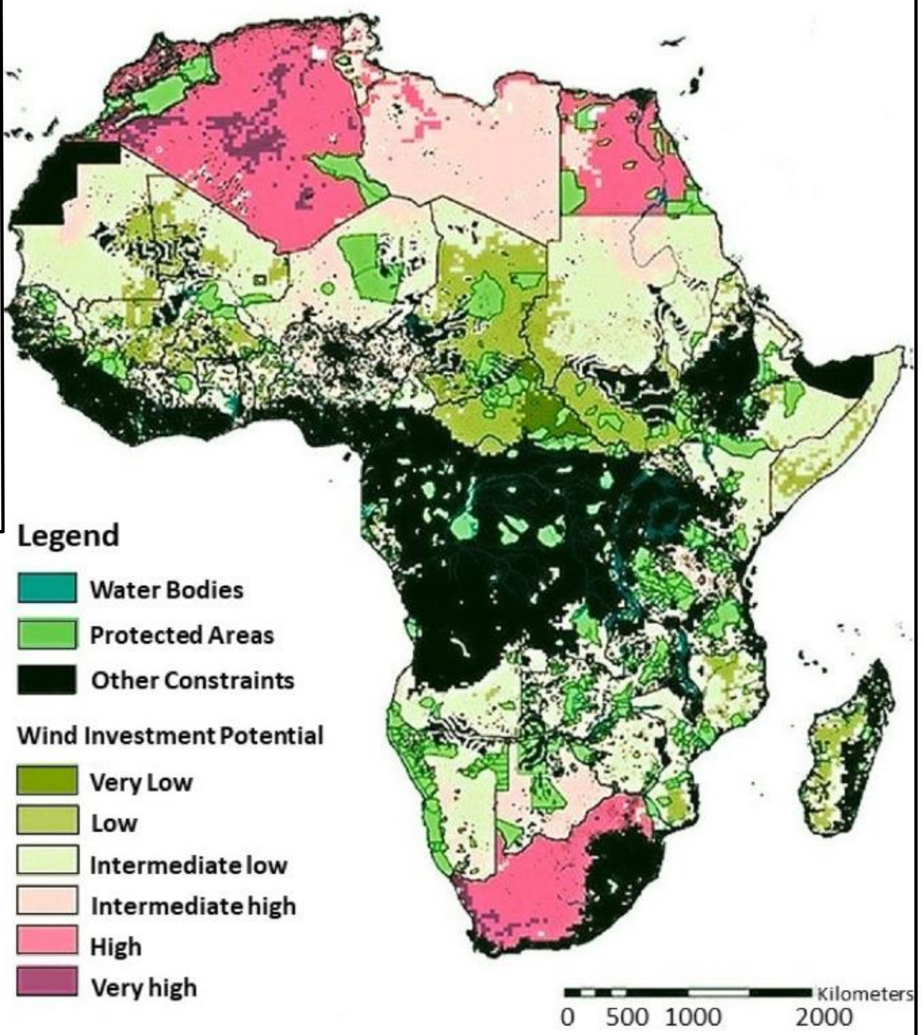


Egypt/ South Africa (Solar):

- High insolation (250 W/m^2)
- High rate of successful PV projects
- Heavy reliance on coal, gas and diesel for electricity
- Low monthly outages
- Political stability

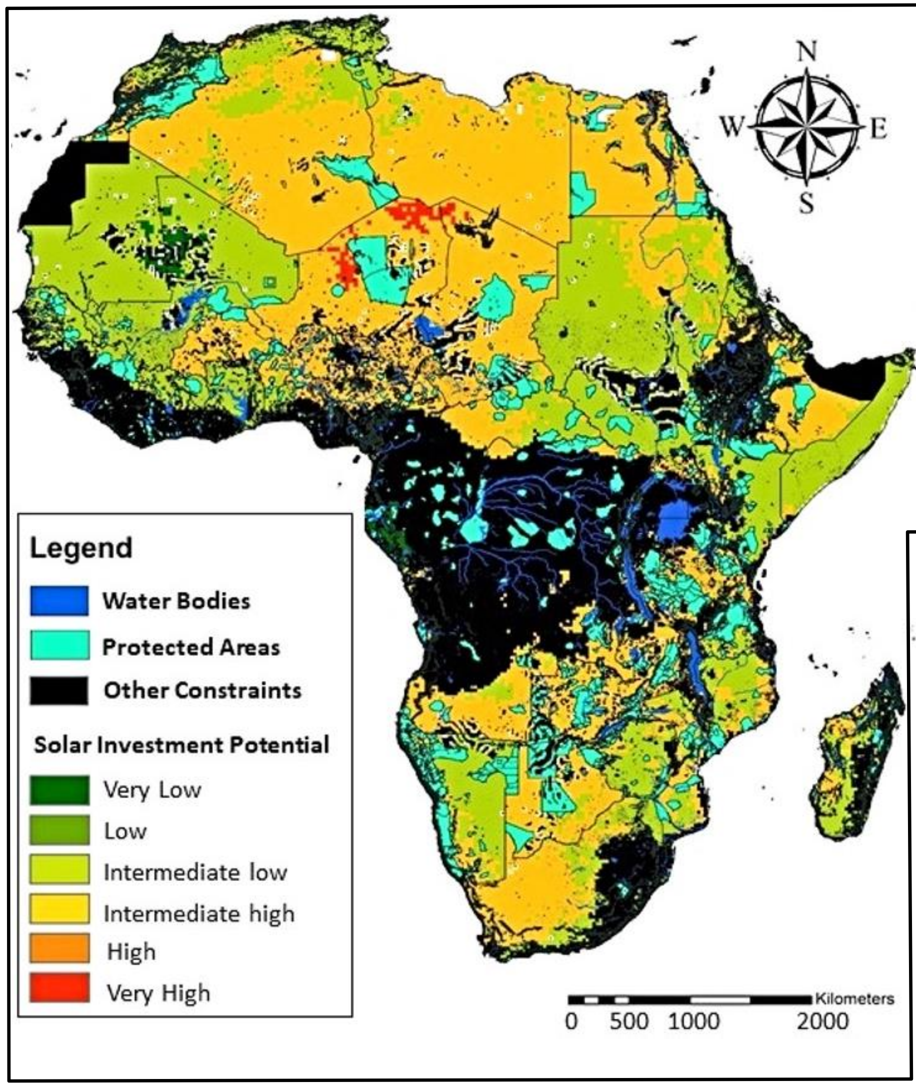
Algeria/ South Africa (Wind):

- Strong winds of >10 m/s at 150 m height)
- High installed wind capacity
- Heavy reliance on coal, gas and diesel for electricity
- Low monthly outages
- Political stability



Solar and Wind Potentials – Philanthropic Investor Perspective

Perspective of investors motivated in improving the electricity situation of a country

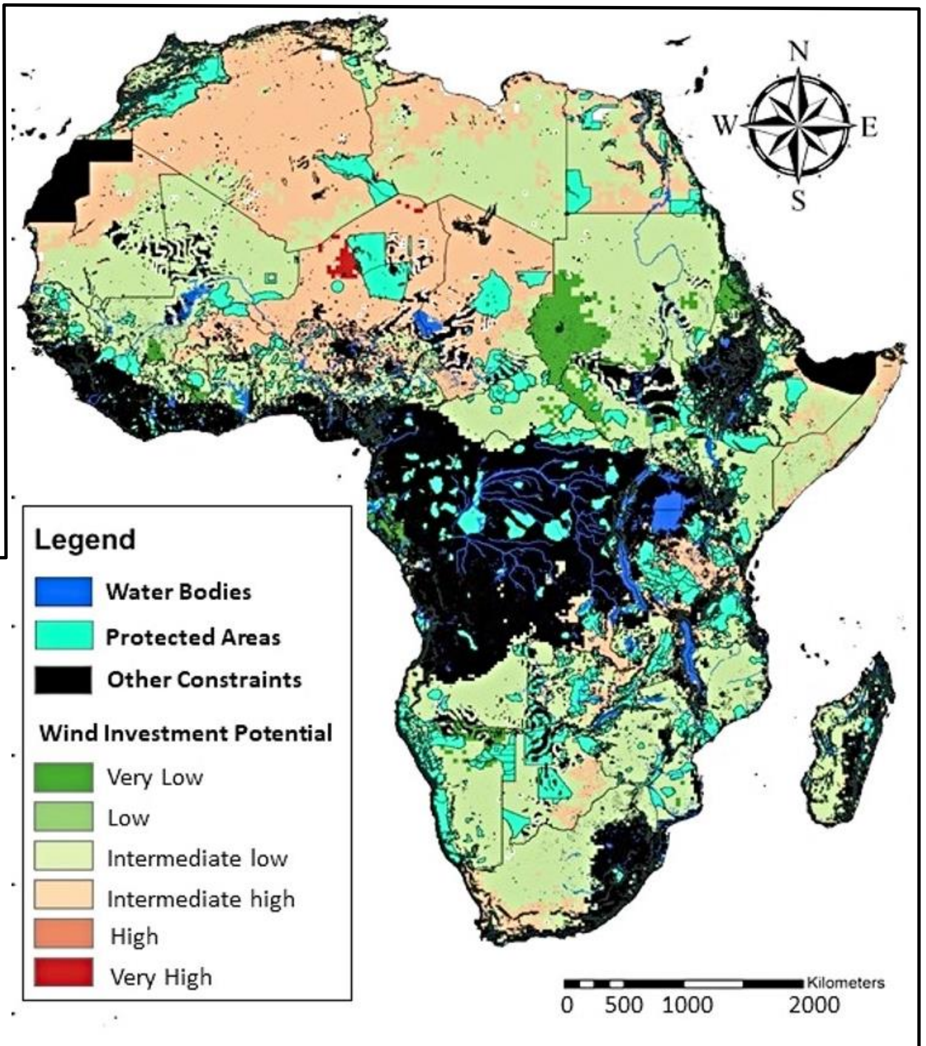


Niger/ Chad (Solar):

- High insolation (230 W/m²)
- Intermediate rate of successful PV projects
- High monthly outages
- Low access to electricity
- Lack of adequate electricity infrastructures

Niger (Wind):

- Strong winds of 10 m/s (150m height)
- High monthly outages
- Low access to electricity
- Lack of adequate electricity infrastructures

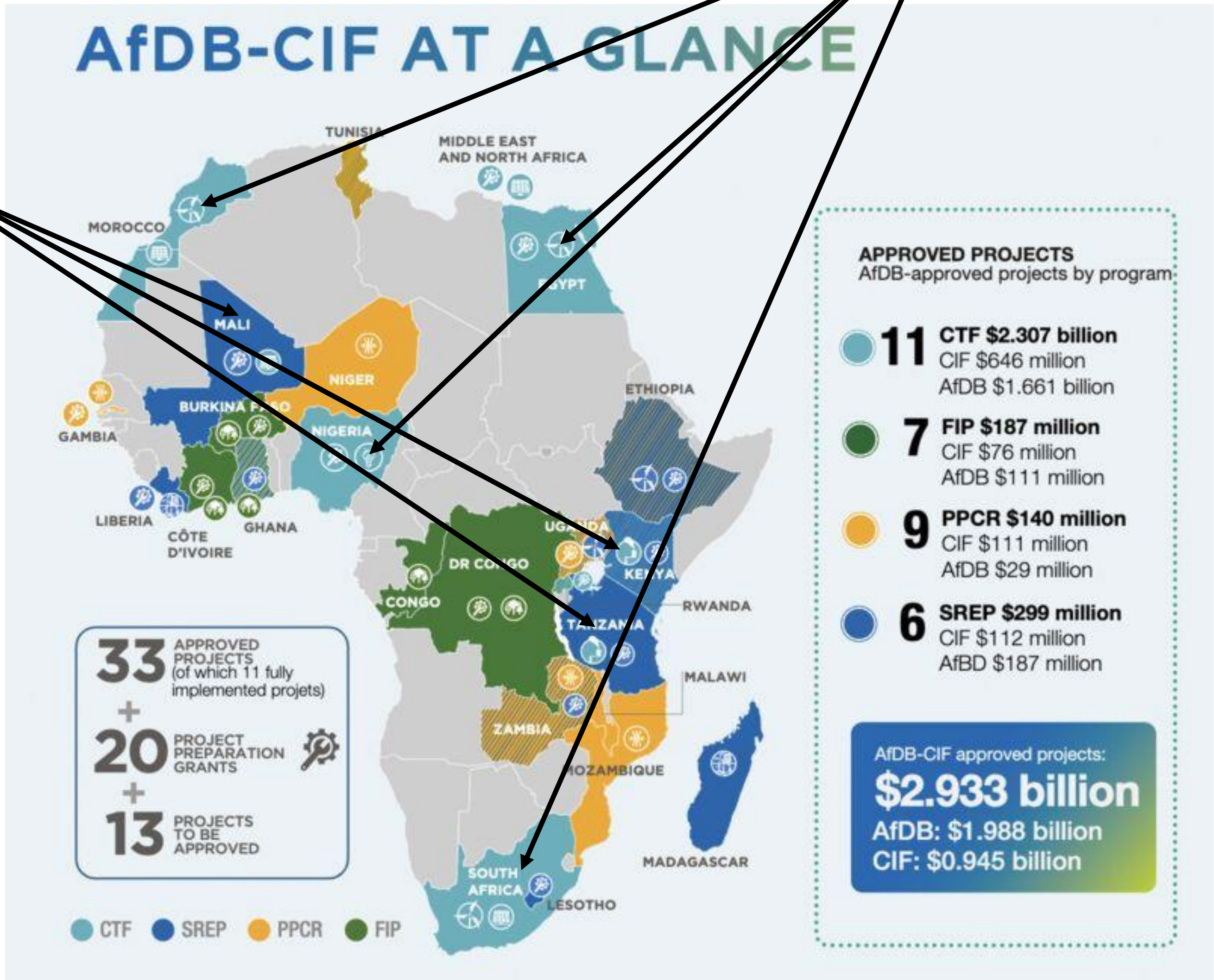


Comparing results with reality

Mapping of investment projects from AfDB-CIF

Egypt, SA, Nigeria and Morocco are recipient of the high investments for the CTF programme

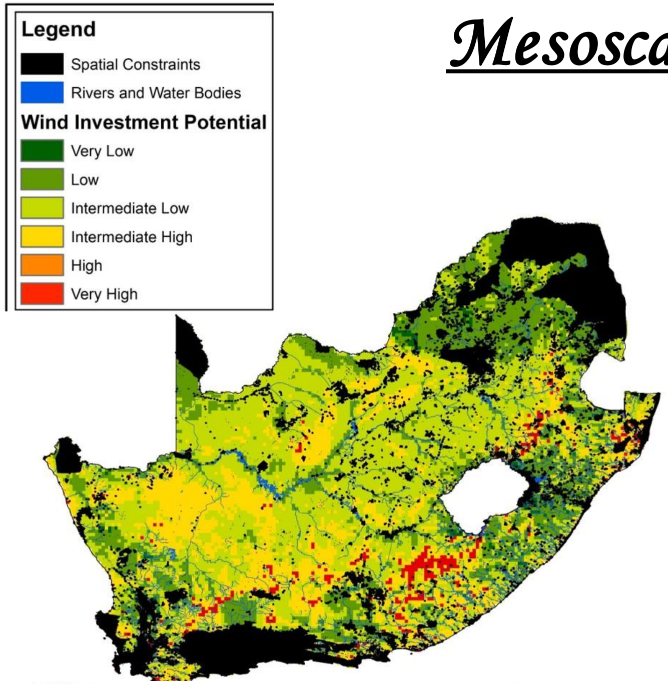
Mali, Kenya and Tanzania are targeted for SREP investments whilst Niger and Chad have higher potentials and lower access to electricity (climate action and philanthropic perspectives)



- Cautious investing in Western Sahara Region – disputed territory
- Programme aims at making significant GHG savings Nigeria has weak energy infrastructures

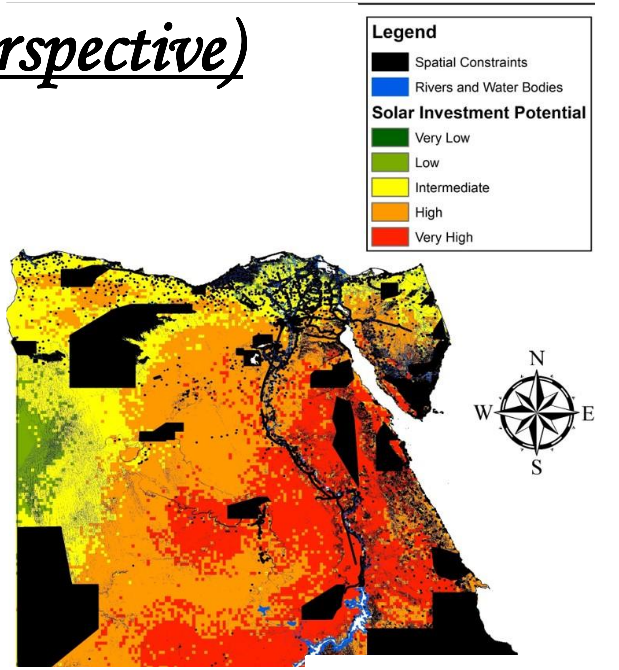
- Clean Technology Fund **(CTF)**
- Forest Investment Program **(FIP)**
- Pilot Program for Climate Resilience **(PPCR)**
- Scaling Up Renewable Energy Program in Low Income Countries **(SREP)**

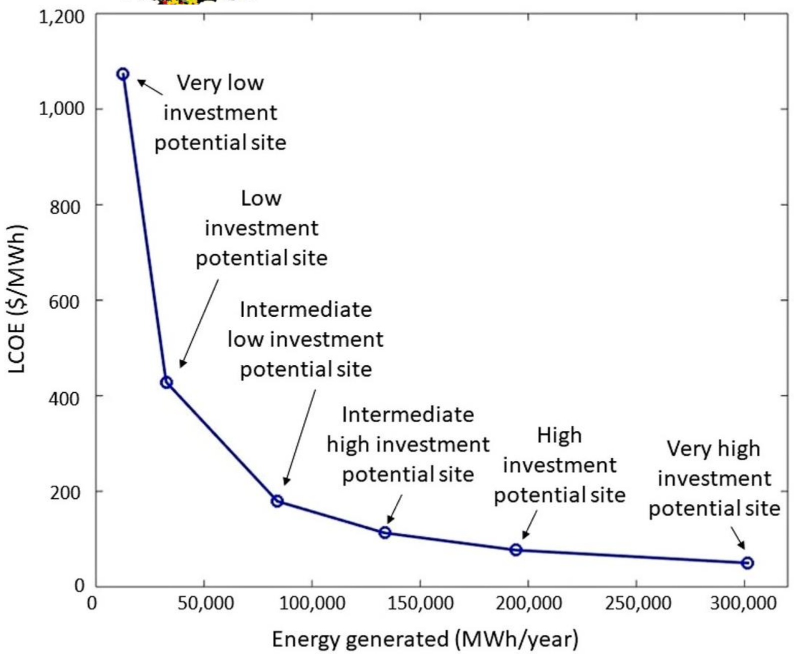
Mesoscale Analysis of best sites (Financial Investor Perspective)



- Construction of a wind farm in a very high investment potential site is \$50/MWh, which is around 16.7% lower than investing in coal-fired power stations (\$60/MWh (Bischof-Niemz and Fourie, 2016))

- Construction of a solar farm in a very high investment potential site is \$58/MWh, which is around 29.7% lower than investing in combined-cycle gas turbines (LCOE of 83/MWh (Tsvetomira 2016)) and 37.0% lower than investing in diesel generators (LCOE of \$93/MWh (Tsvetomira 2016))

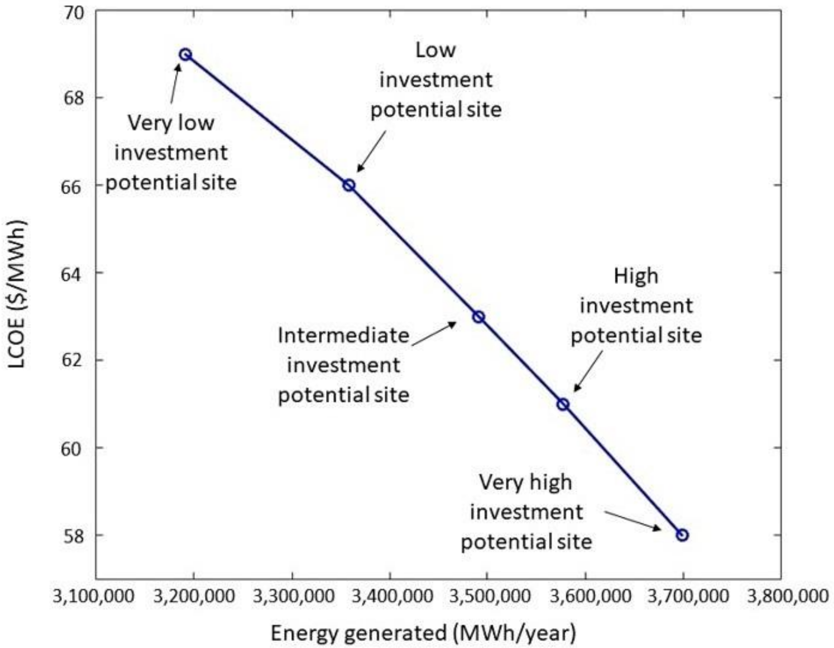




- It is still cheaper to invest in solar farms in the worst sites in Egypt (LCOE of \$69/MWh) than to invest in combined-cycle gas turbines and diesel generators

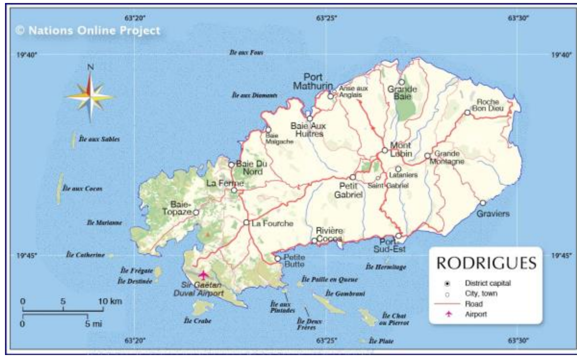
- While the financial viability of RE investments in hotspots are favorable, it is important to dismantle politico-institutional and technical barriers to adoption

Doorga, Eyre and Hall(2022a)



The Case of Small Island States

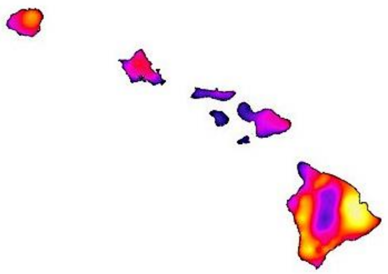
The Small Island Context

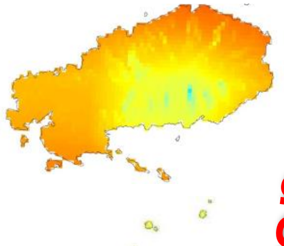


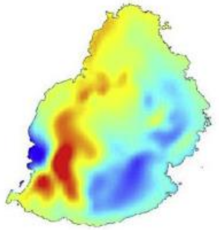
	Hawaii	Mauritius	Rodrigues
Fossil fuel for electricity generation	77%	78%	89.8%
Land constraints	Islands have significant land constraint issues with diminishing land area due to sea level rise and competing interest for land space		
Biodiversity	Islands have relatively high level of variety and endemism due to their remoteness and marginal levels of development		

Applying the framework

For small islands, factors which include Political, Institutional, Energy Demand, and Decarbonization Priorities do not vary significantly on spatial scales

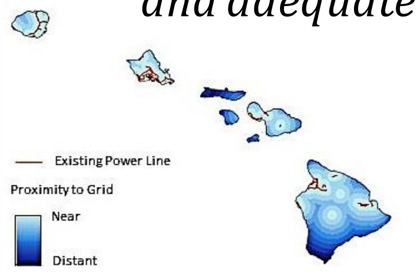


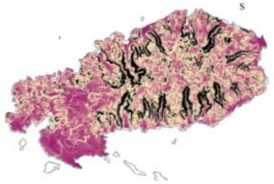


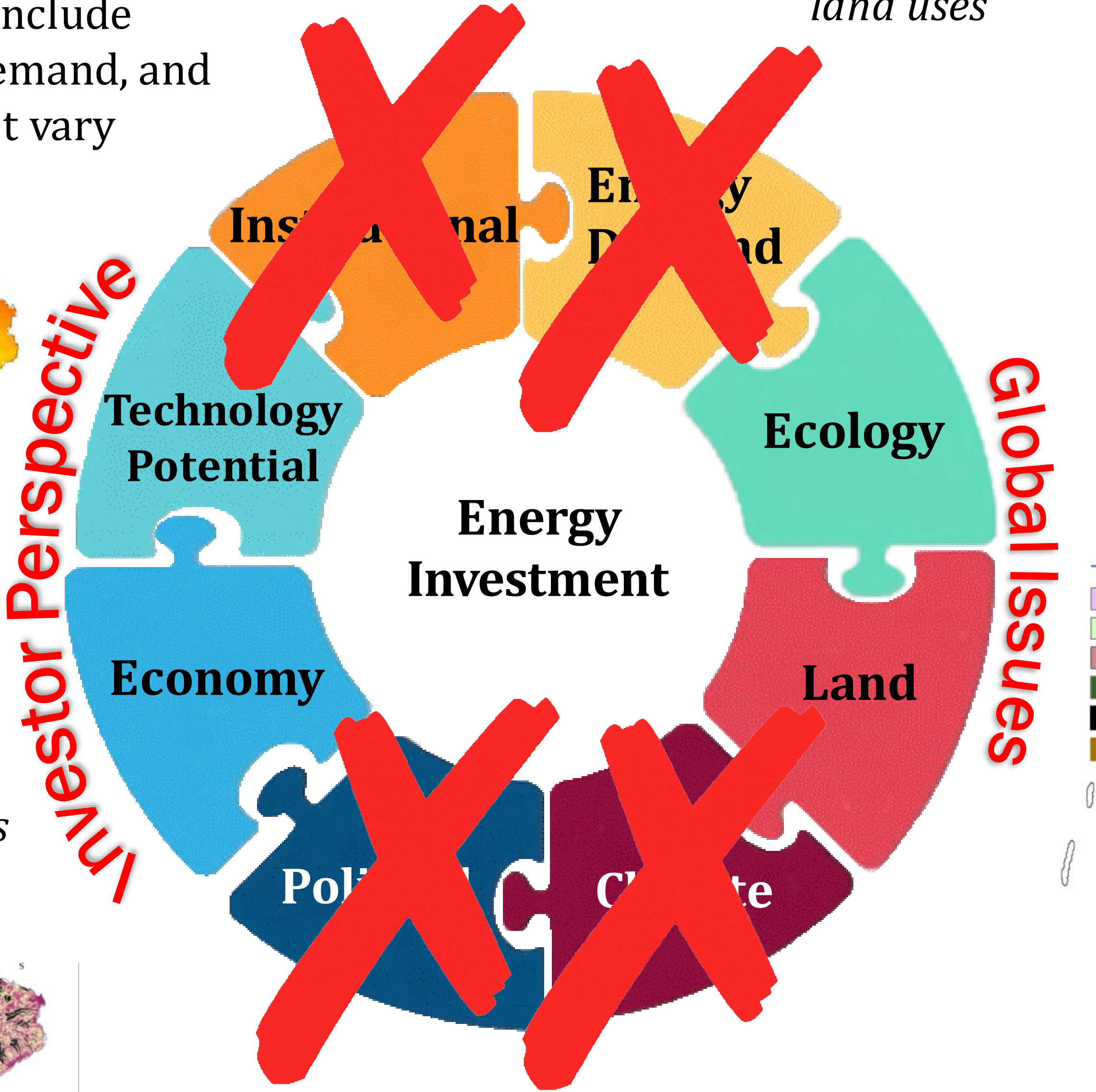


Climatic Parameters

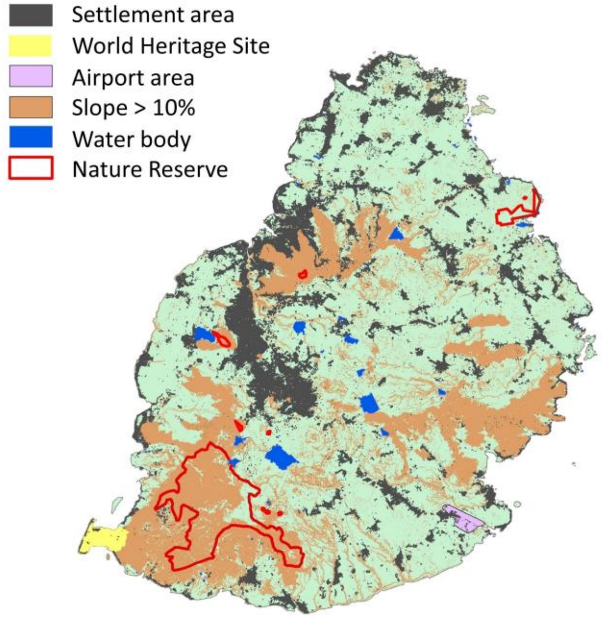
Proximity to infrastructures and adequate slopes

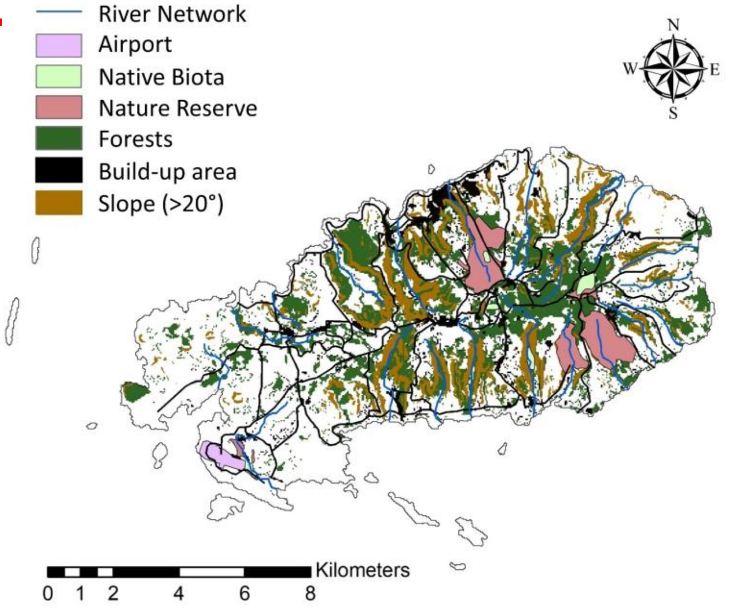




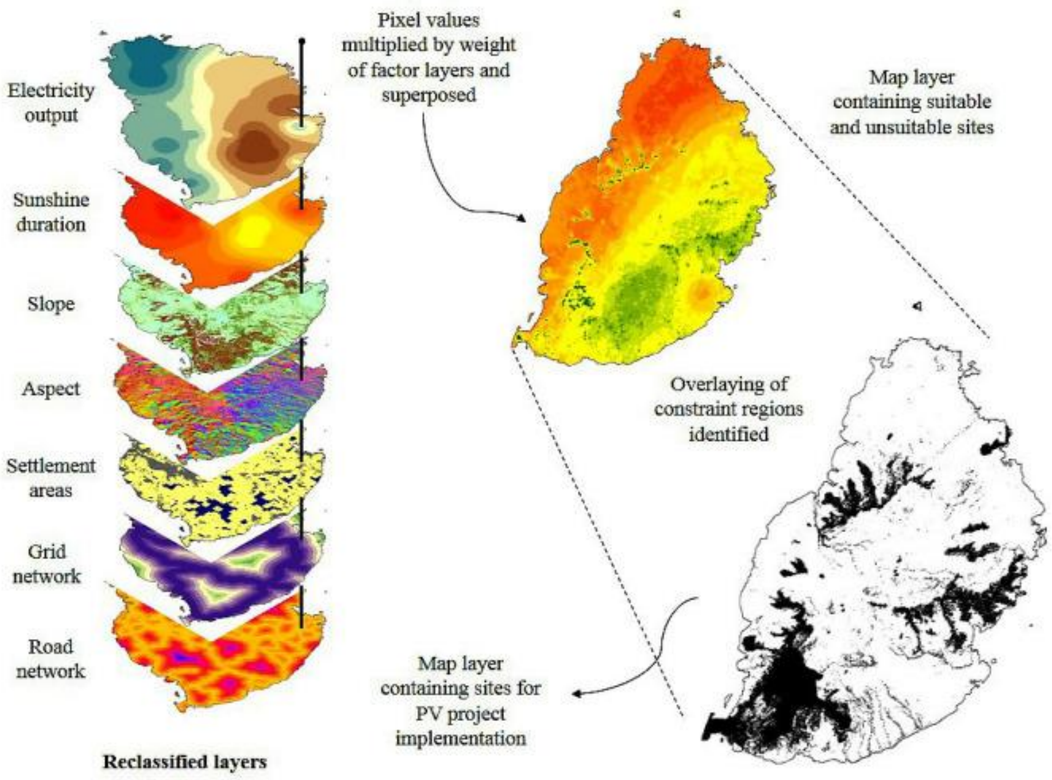


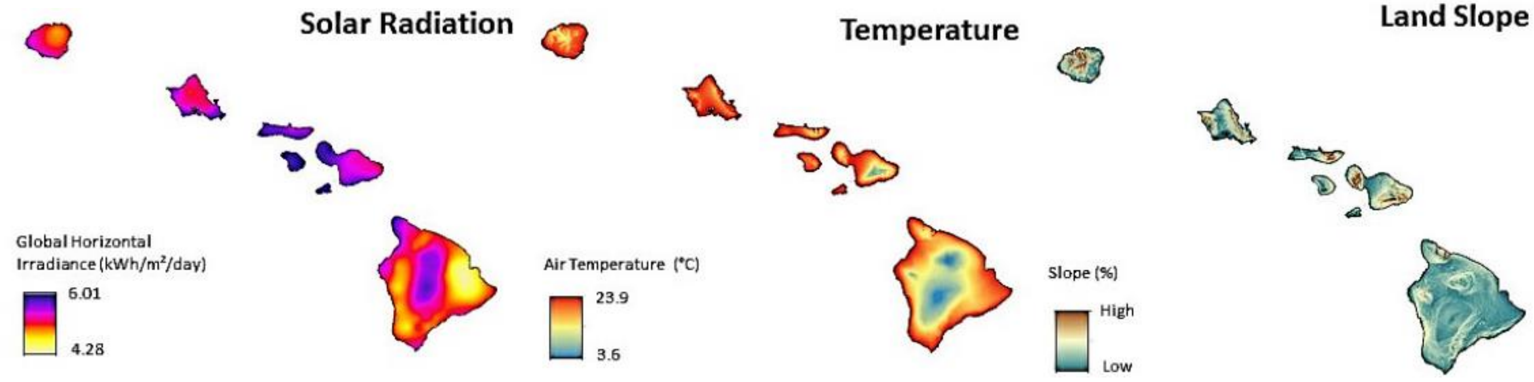
Ecological and Socio-economic land uses

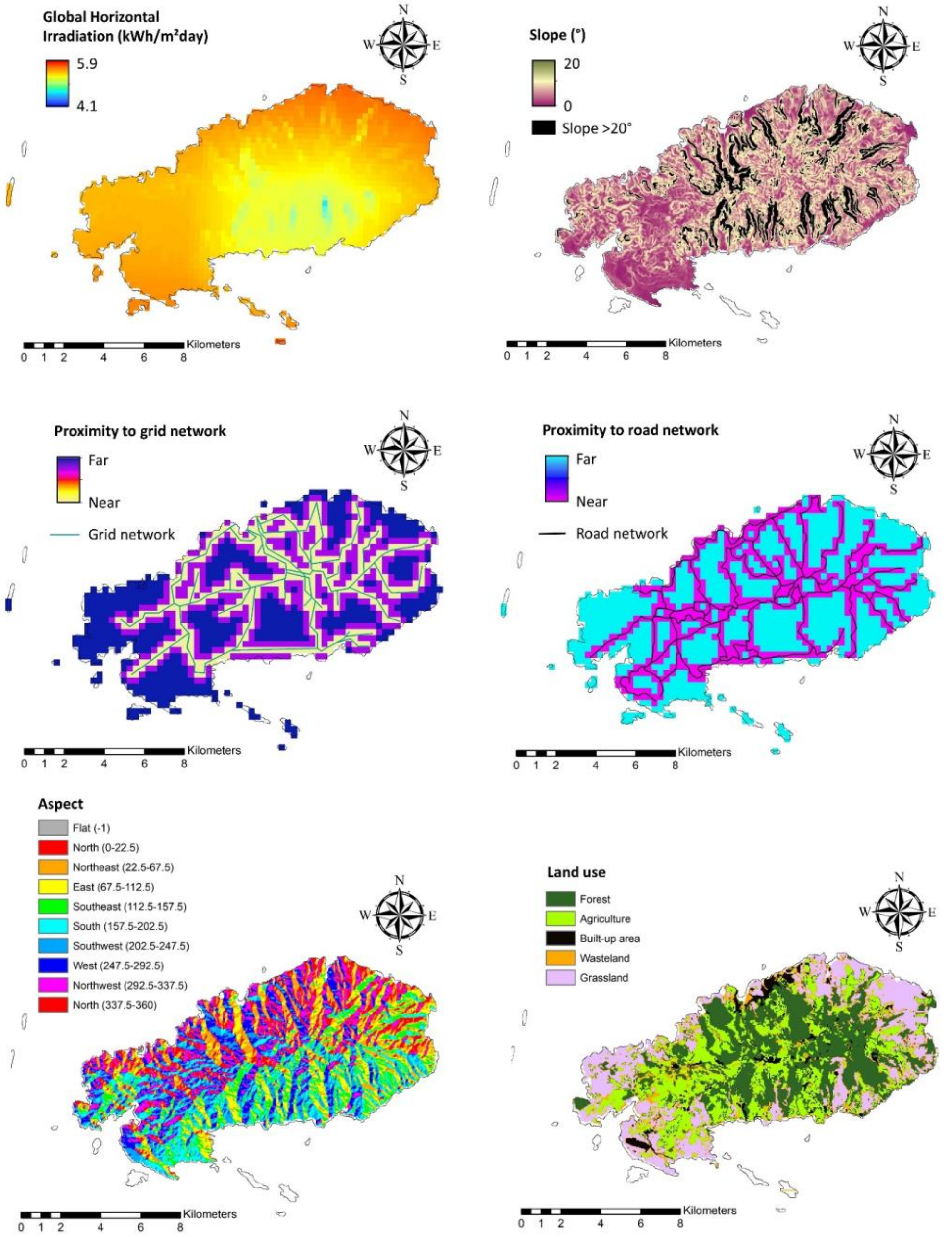


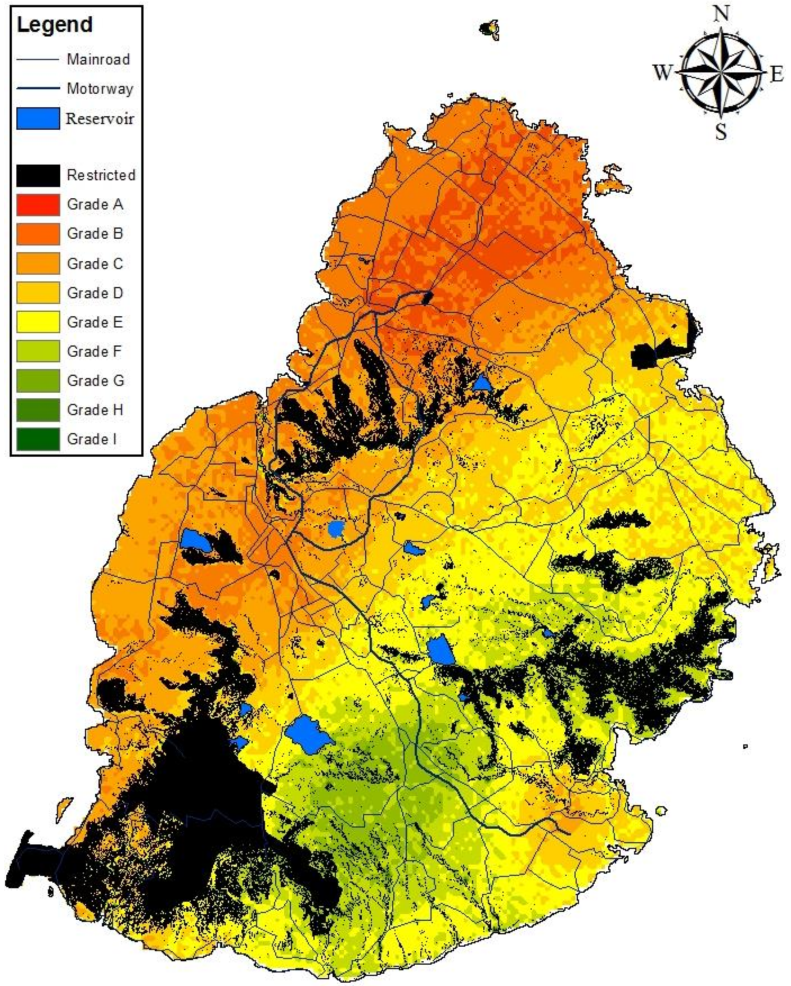


Using the MCDA Process



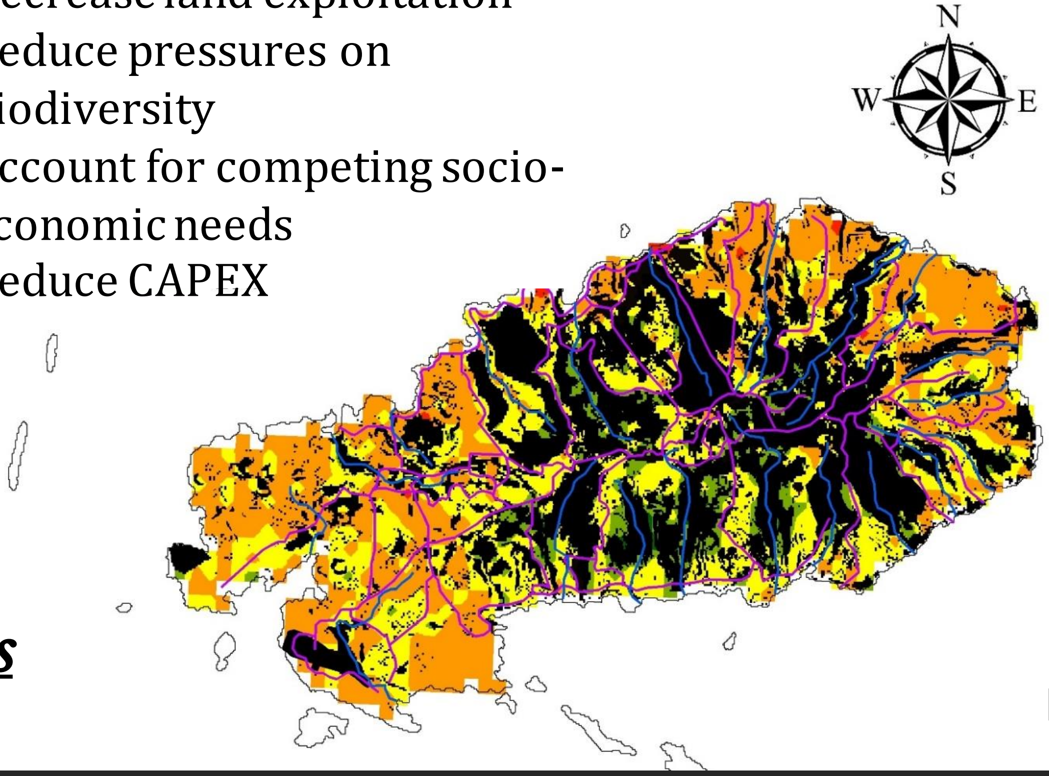






Applying the MCDA framework result in a metric that helps identify strategic regions where to invest:

- Optimize yield
- Decrease land exploitation
- Reduce pressures on biodiversity
- Account for competing socio-economic needs
- Reduce CAPEX



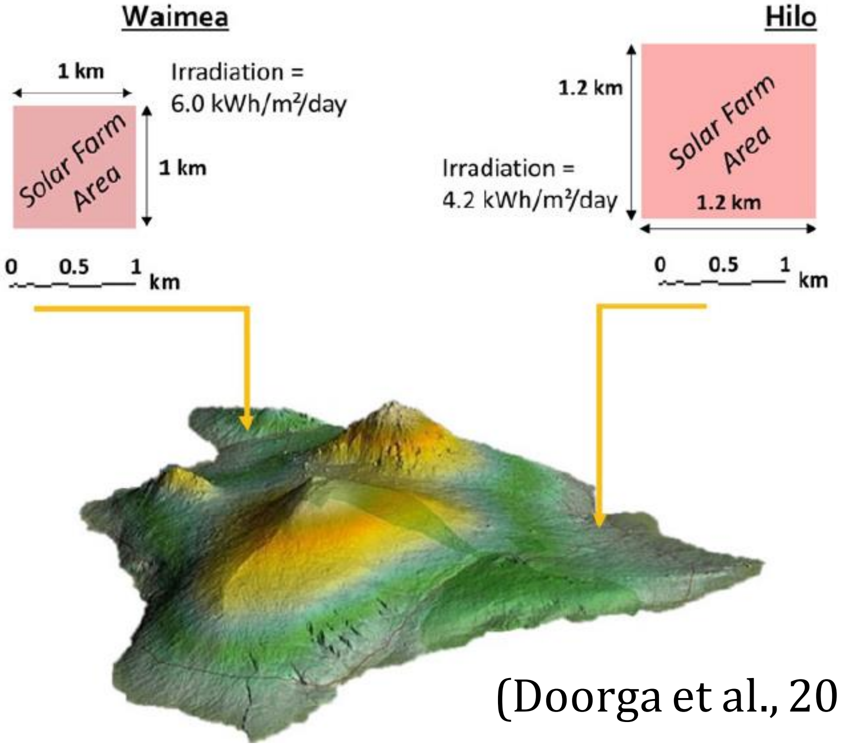
Graded sites for Solar Investments

Doorga et al. (2022b).

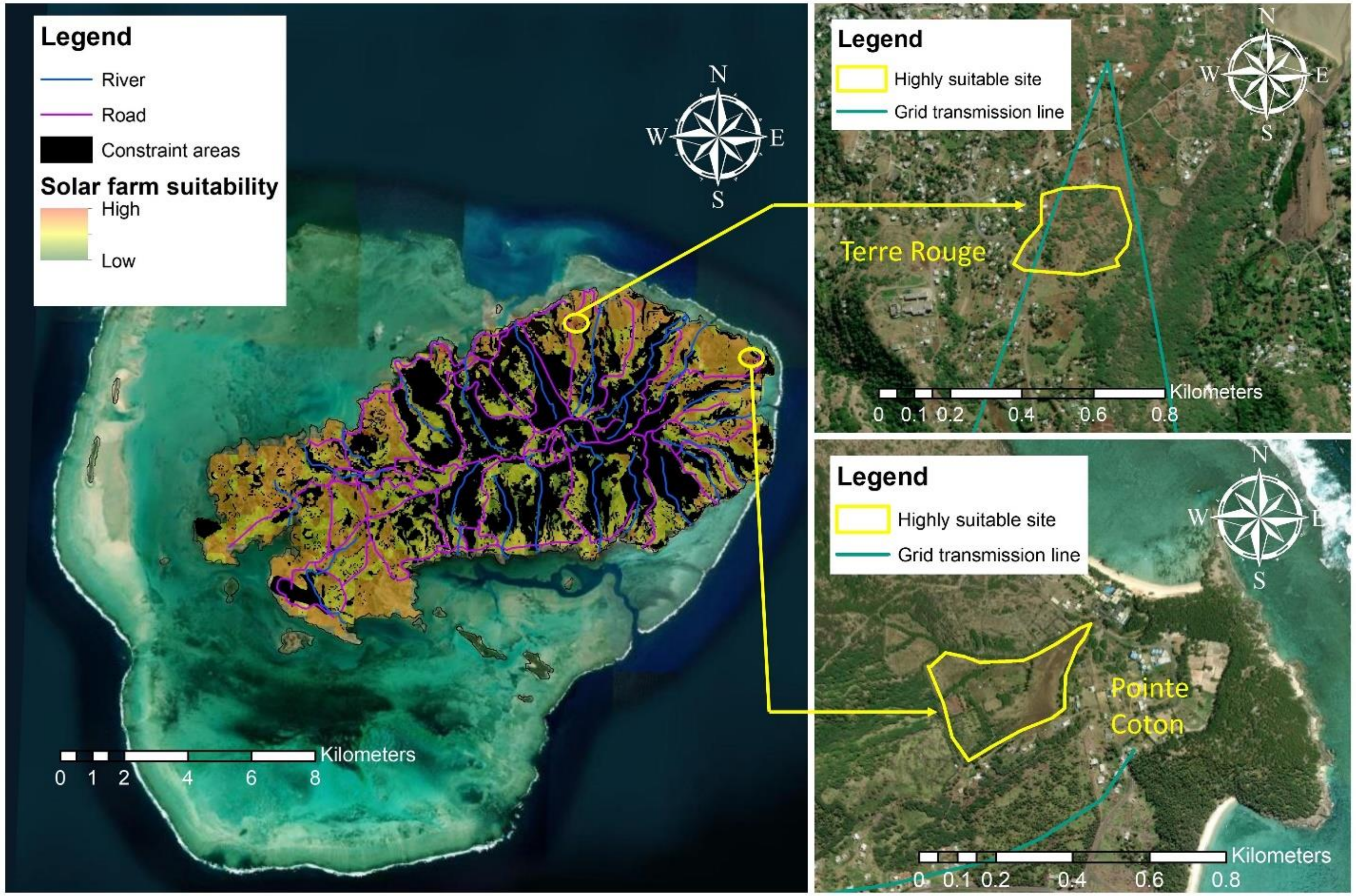
Addressing land and biodiversity issues for an expanding RE context

Land Issue: The MCDA framework helps identify optimum areas where to invest [Maximum yield in minimum space].

Investing in Waimea would necessitate less land requirements than Hilo for the same energy generation output (Land savings 30%)

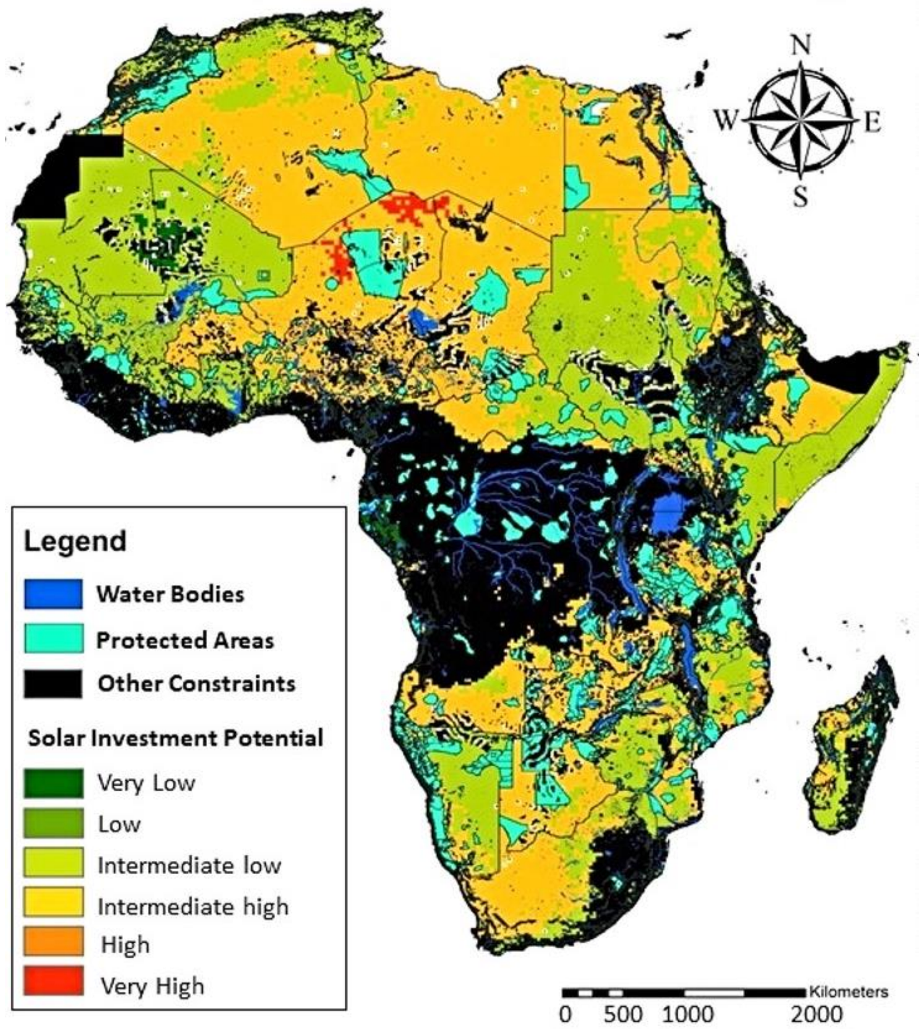


(Doorga et al., 2022b)



Biodiversity Issue: The MCDA analysis enables identification of less productive lands, outside of biodiversity areas where RE investments would impact less on natural ecosystems

From Continental to Island Scale

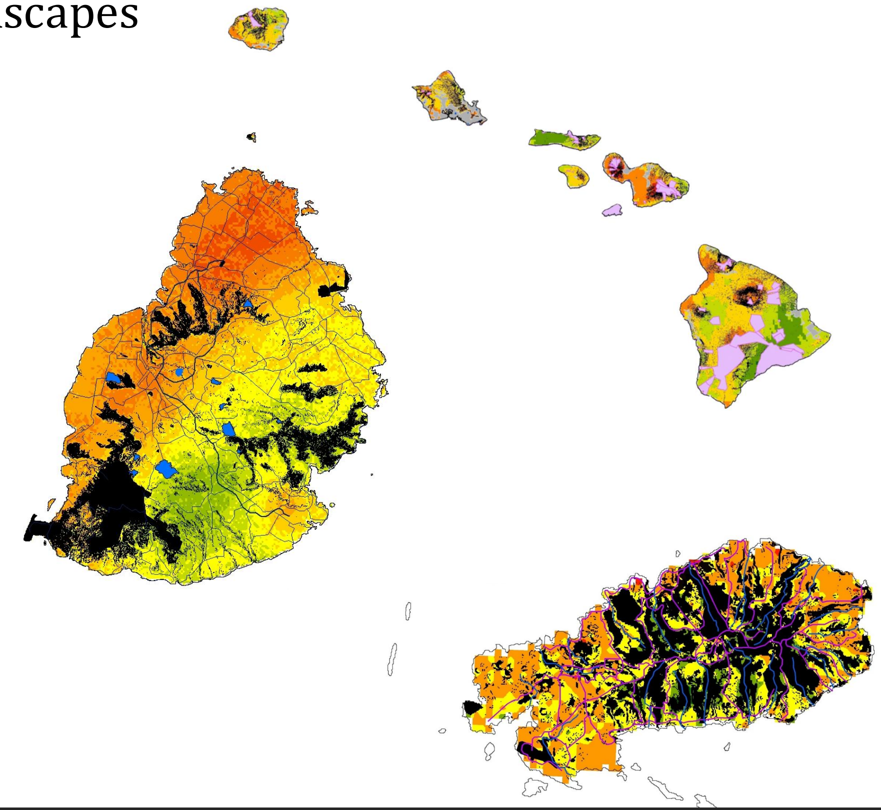


Although the context may be different:

- Continental scale: Identification of strategic regions for effective decarbonization, factoring-in political and institutional concerns to foster coordination among donors
- Island scale: Identification of strategic regions where land use exploitation and biodiversity issues are minimized to enable the conservation of pristine landscapes

A multi-criterial framework is important as it treats the RE investment issue as an interconnected problem

[*Ecology, Land, Energy, Climate, Political, Socio-economic and Institutional*]



‘The future demands of us critical decisions in the face of worldwide conflicts which increase the number of the excluded and those in need.’

-Pope Francis, Address to the UN General Assembly

Multi-criterial decision-making [RE investments] permits the inclusion of several spheres of the human existence, from the environmental to socio-political and institutional settings for strategic & effective investments.

CONCLUSION

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