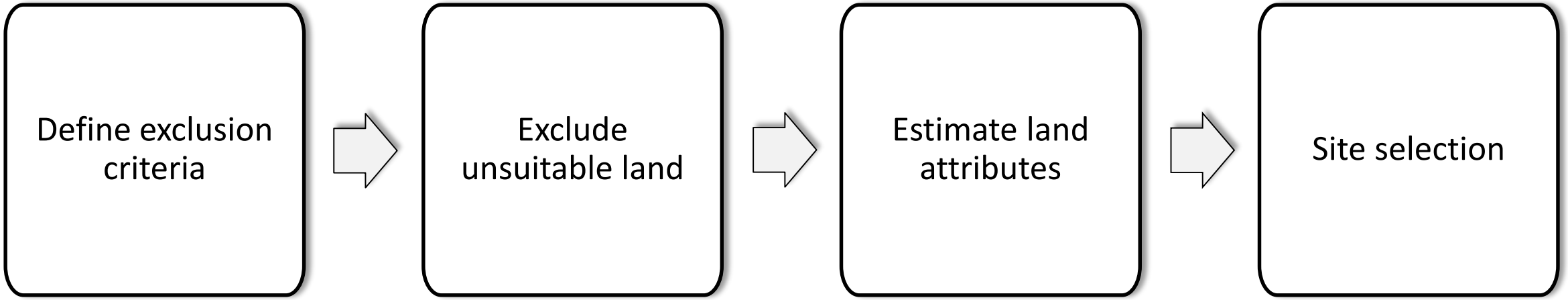
Geospatial Identification of Solar PV Sites

Kabul, Jalalabad, Kandahar, Herat and Mazar

WORLD BANK GROUP

Identification of suitable sites for the installation of solar PV plants



Geography
Environment
Population
Land ownership
Protected areas
Natural Hazards
Climate Change

Resource quality, electricity generation potential, capacity factor, LCOE, etc.

Proximity to five major load centers: **Kabul, Jalalabad, Herat, Kandahar, and Mazar**

Criteria for Land Exclusion

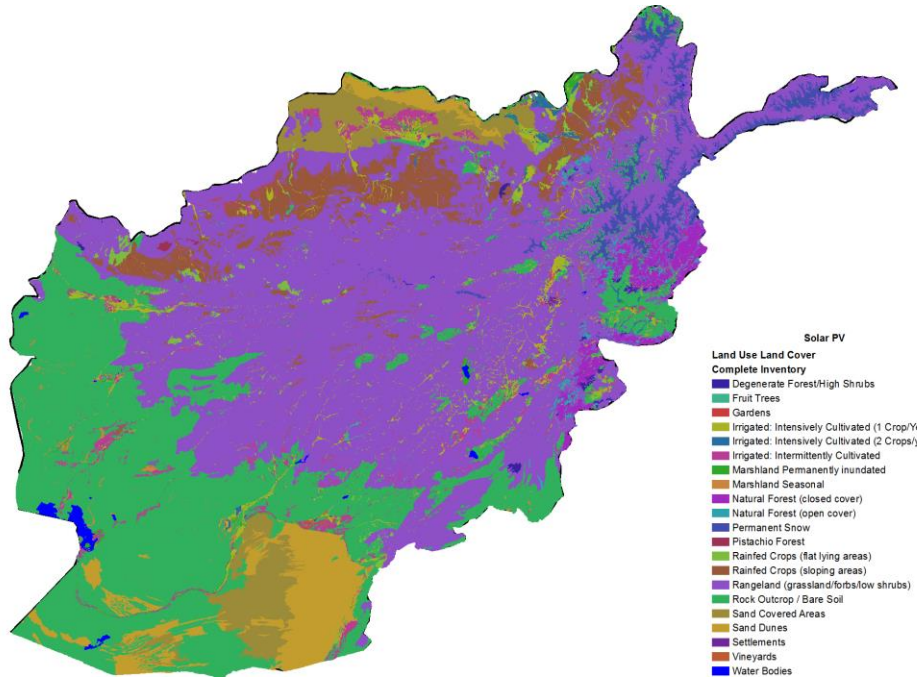
Parameter	PV	Unit
Lakes	Value >= 500	Distance in meters
Rivers	Value >= 500	Distance in meters
Slope	Value <= 10	Slope in percentage
Elevation	Value <= 4000	Elevation in meters
Protected Areas	Value >= 500	Distance in meters
Land Use/Land Cover	Value > 0	Distance in meters
Airports	Value >= 2000	Distance in meters
Airfields	Value >= 100	Distance in meters
Population	Value <= 200	Density per square km

+

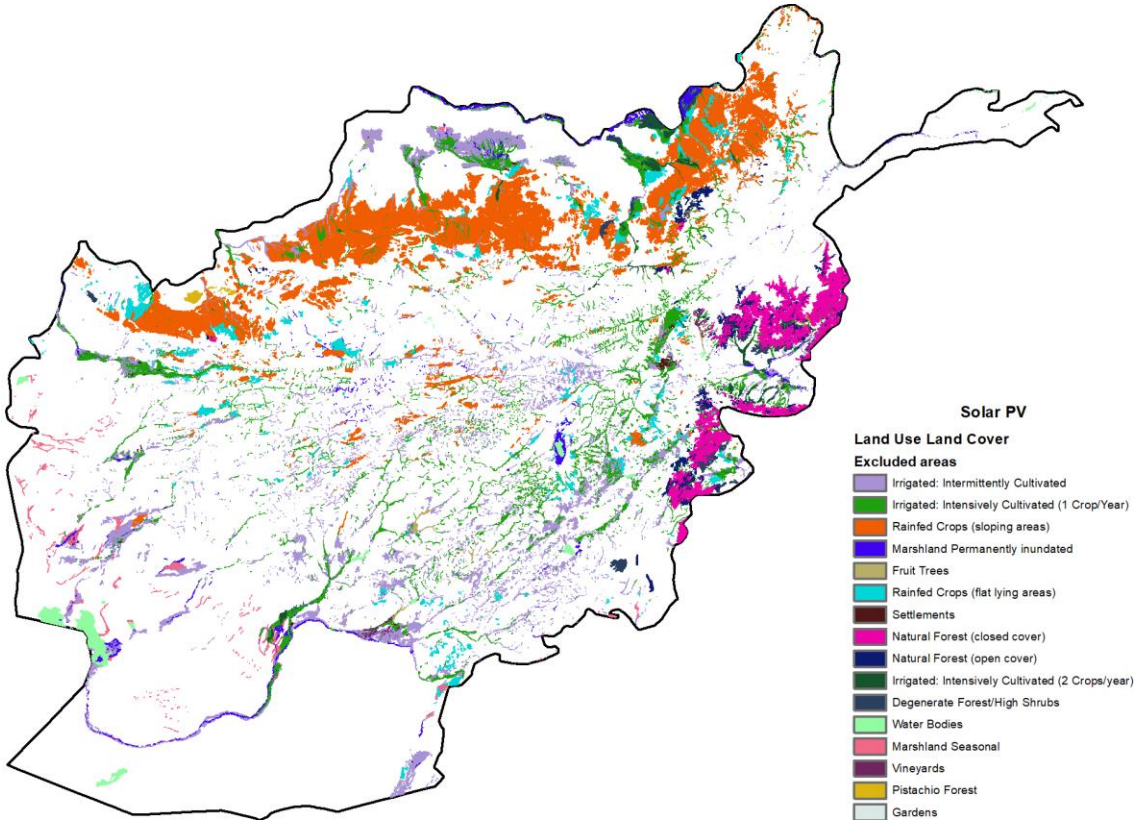
Climate change and Natural Hazards
Flash flood
Fluvial flood
Avalanche
Earthquake
Slow bedrock landslides
Rapid bedrock landslides
Rapid cover material landslides

Criteria for Land Use and Land Cover Exclusion

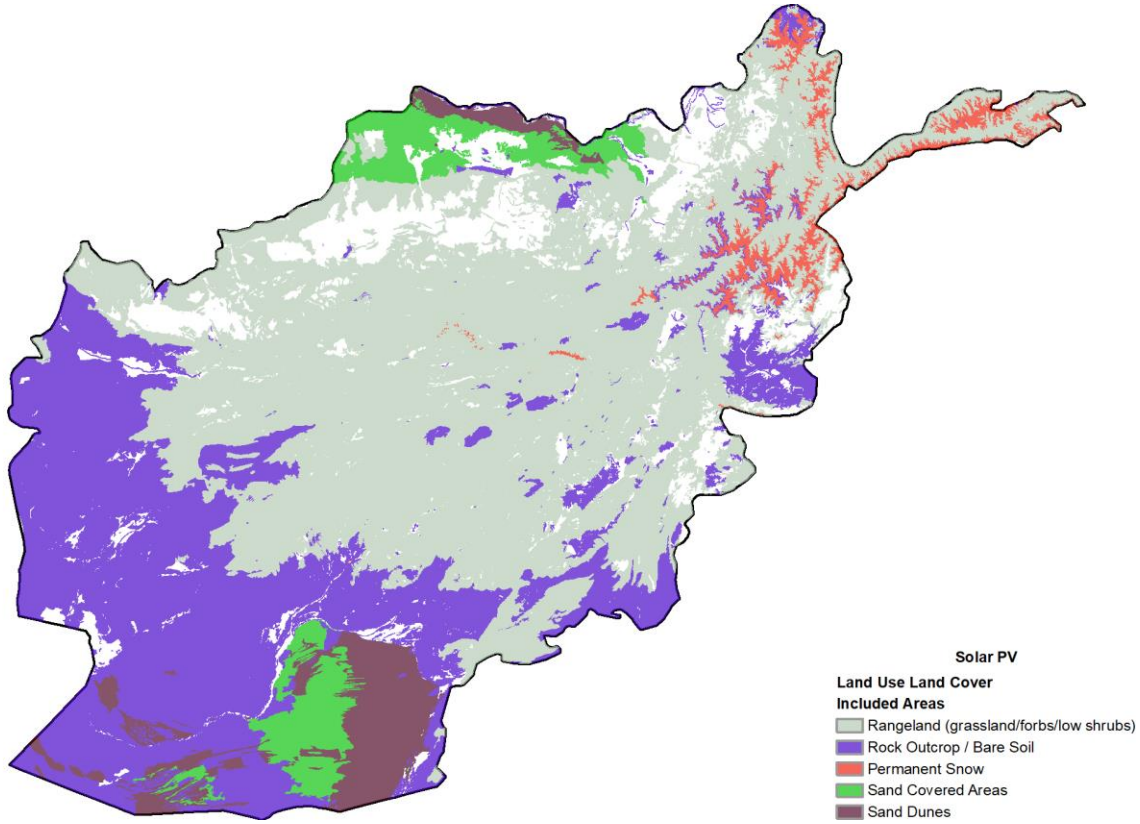
Land Use Land Cover Class	Inclusion Criteria
Rangeland (grassland/forbs/low shrubs)	Included
Rock Outcrop / Bare Soil	
Permanent Snow	
Sand Dunes	
Sand Covered Areas	
Irrigated: Intermittently Cultivated	Excluded
Irrigated: Intensively Cultivated (1 Crop/Year)	
Rainfed Crops (sloping areas)	
Marshland Permanently inundated	
Fruit Trees	
Rainfed Crops (flat lying areas)	
Settlements	
Natural Forest (closed cover)	
Natural Forest (open cover)	
Irrigated: Intensively Cultivated (2 Crops/year)	
Degenerate Forest/High Shrubs	
Water Bodies	
Marshland Seasonal	
Vineyards	
Pistachio Forest	
Gardens	



Land Use and Land Cover Exclusion/Inclusion

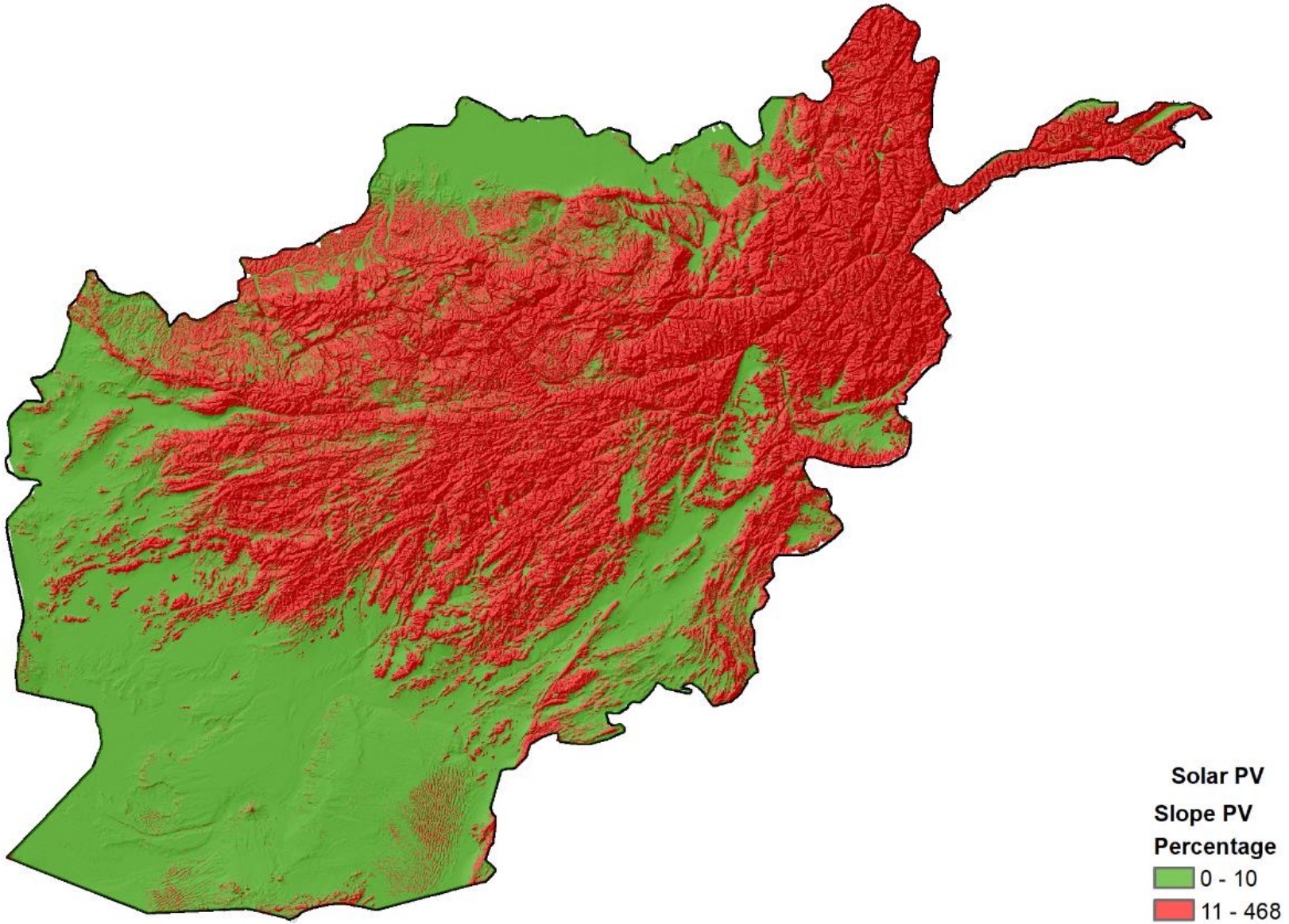


Excluded Land

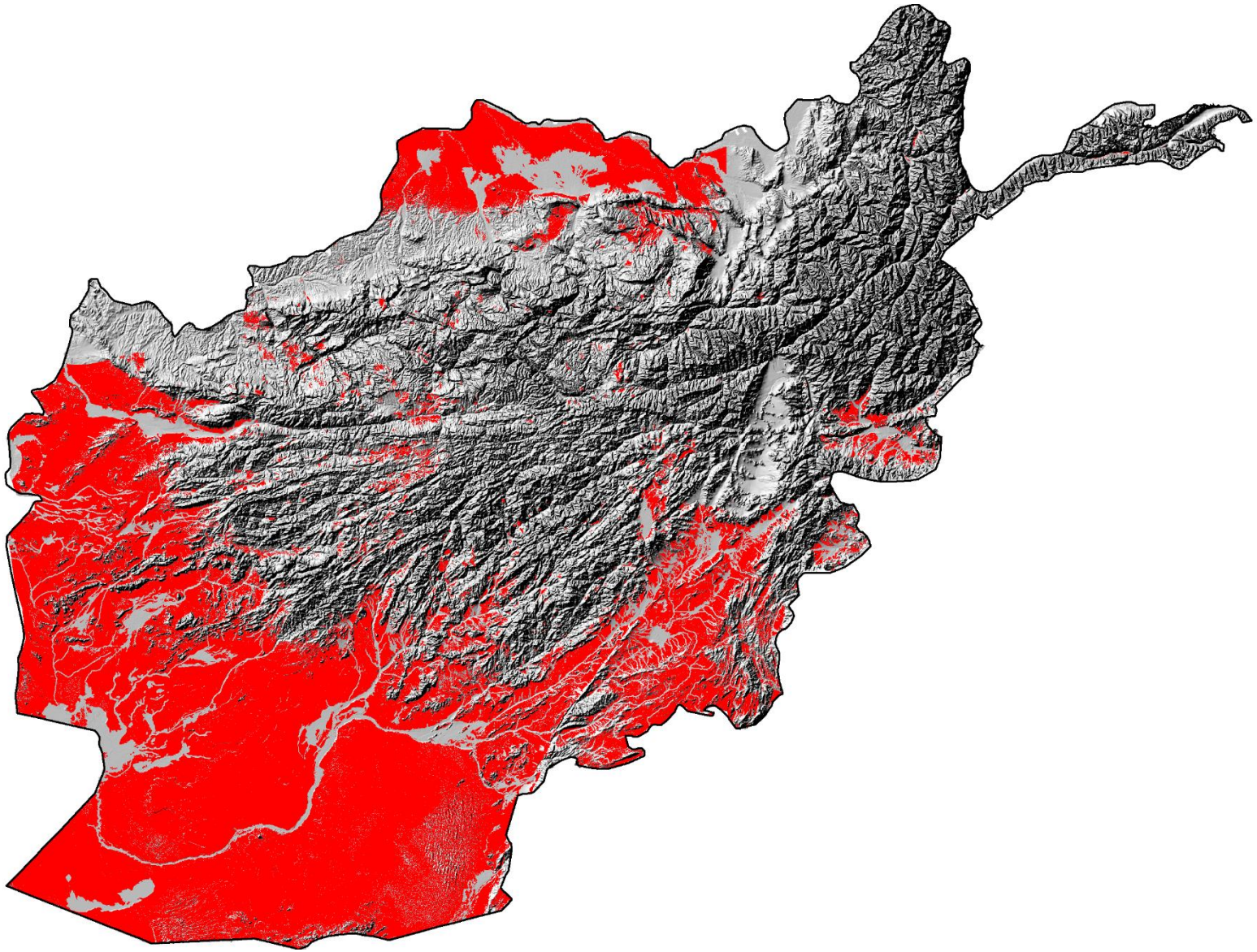


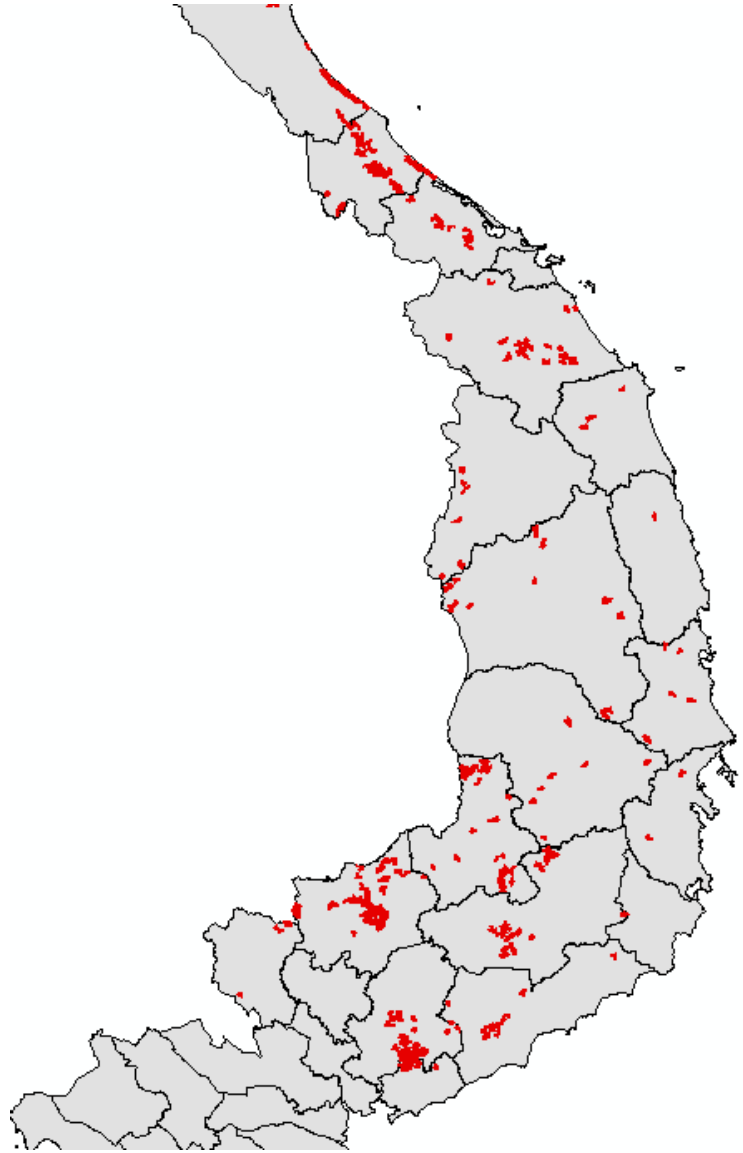
Included Land

Sloping areas

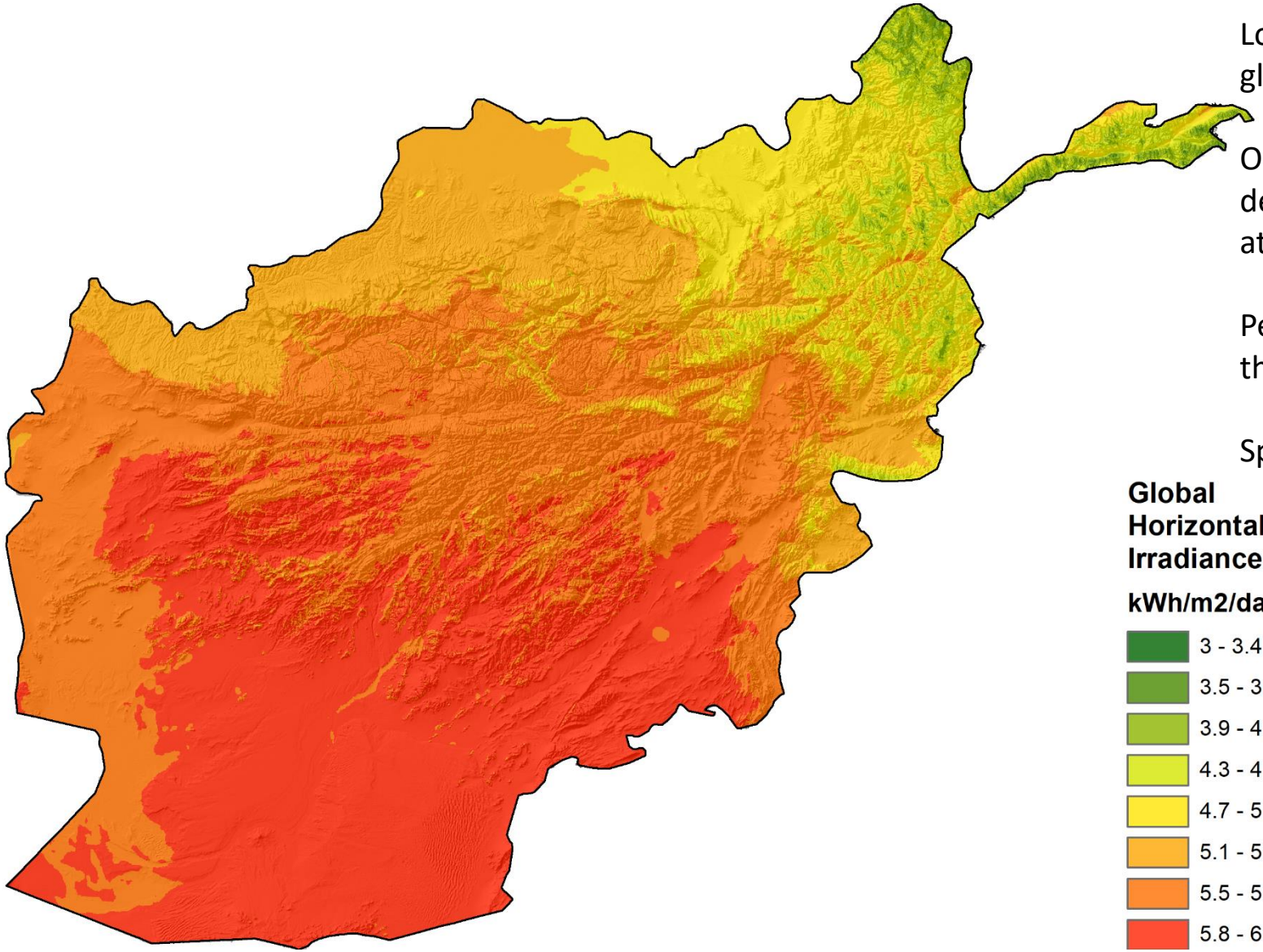


Suitable land at the Country Level





Global Horizontal Irradiance

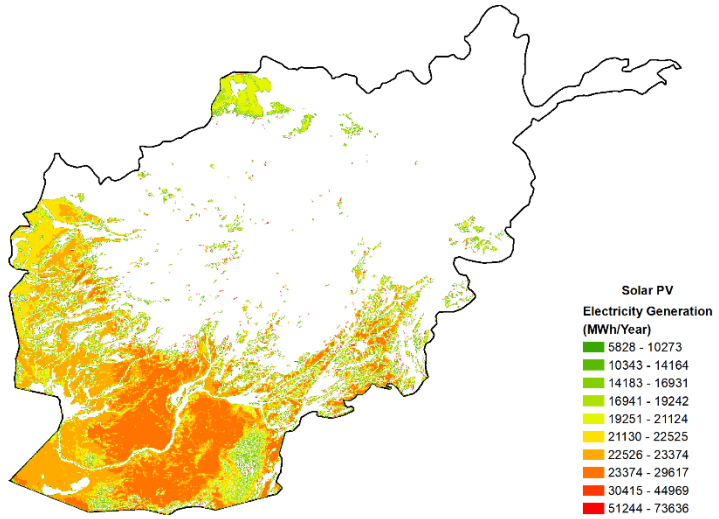


Long-term yearly average of daily totals of global horizontal irradiation (GHI) in kWh/m^2

Output from the global solar model SolarGIS derived from satellite digital images and atmospheric datasets

Period: from 1994/1999/2007 (depending on the region) to 2015

Spatial resolution: 30 arc-sec (900 m)

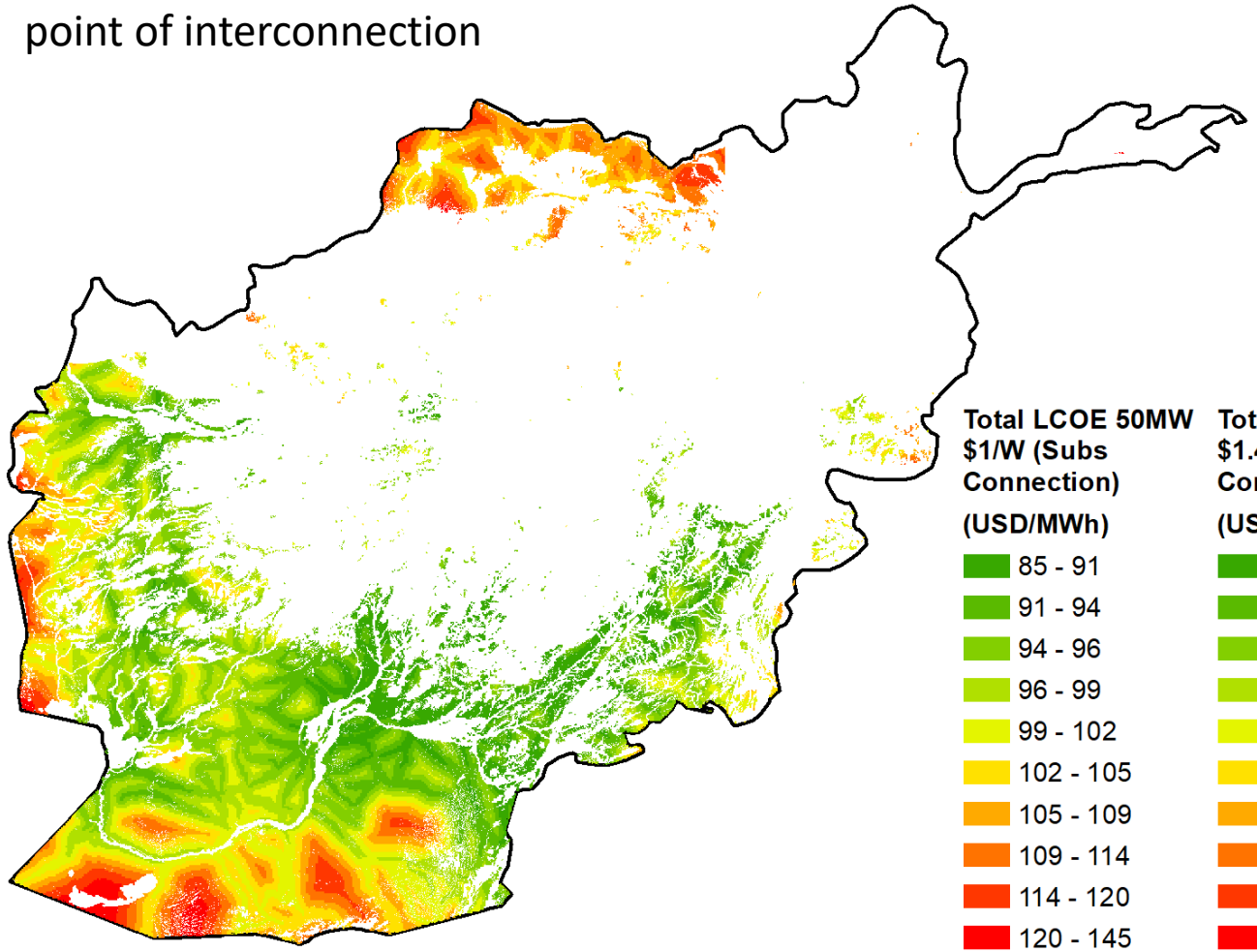


Cost Estimates

Parameter	Solar PV	Unit	Notes
Capital cost	**1,000,000**	**(USD/MW)**	Capital cost of the generation technology. The capital cost for wind technology assumes Class III turbines
Variable O&M cost of generation	**0**	**(USD/MWh)**	Variable operations and maintenance cost of generation
Fixed O&M cost of generation	**15,000**	**(USD/MWh)**	Fixed operations and maintenance cost of generation
Transmission cost	**990**	**(USD/MW/km)**	Capital cost for a transmission line
Substation cost	**175,000**	**(USD/MW)**	Cost of a substation. This cost is added to any new interconnections to represent the average cost of construction of a new substation
Road cost	**407,000**	**(USD/km)**	Capital cost for the construction of a new access road
Economic discount rate	**12.5%**	**(%)**	Cost of capital or interest rate used to determine the present value of future cash flows. This discount rate is used to estimate the LCOE

LCOE

Average cost of every unit of electricity generated over the lifetime of a project at the point of interconnection

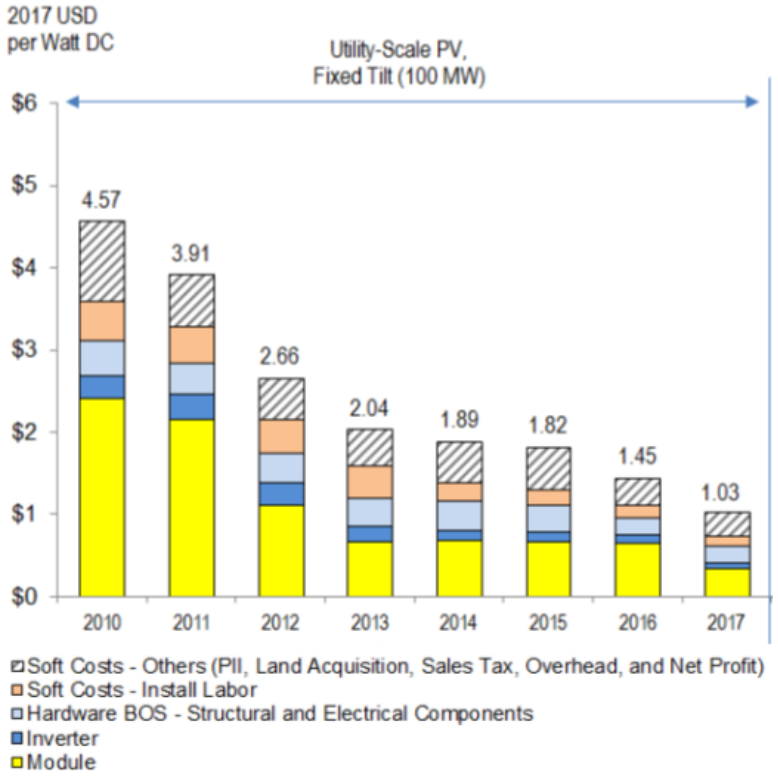


Solar PV

Total LCOE 50MW $1/W (Subs Connection) (USD/MWh)	Total LCOE 50MW $1.4/W (Subs Connection) (USD/MWh)
85 - 91	111 - 117
91 - 94	117 - 120
94 - 96	120 - 123
96 - 99	123 - 126
99 - 102	126 - 130
102 - 105	130 - 133
105 - 109	133 - 137
109 - 114	137 - 142
114 - 120	142 - 147
120 - 145	147 - 181

The LCOE is calculated as the sum of 3 components:

- **Generation** LCOE;
- **Interconnection** LCOE; and
- **Road** LCOE



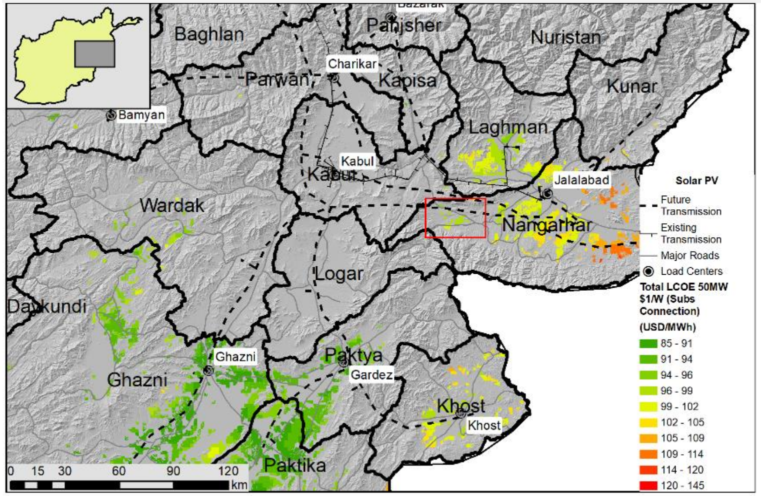
List of Potential Sites

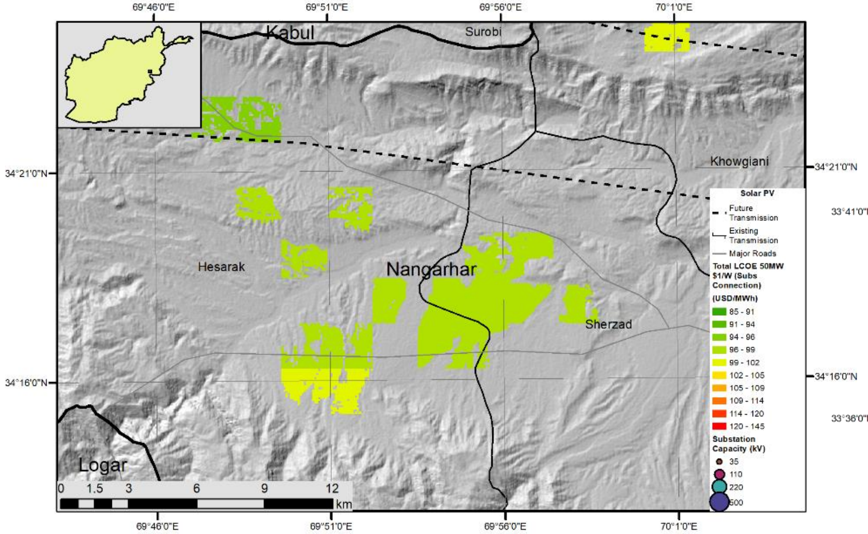
Site Label	Province	Districts	Distance from Load center
Kabul 1	Nangarhar	Hesarak, Sherzad	70 km
Kabul 2	Ghazni	Wali Muhammad-e-Shahid, Ghazni, Khwaja Umari	120 km
Kabul 3	Paktya	Zurmat, Gardez, Ahmadaba	100 km
Kabul 4	Laghman	Mehtarlam	90 km
Jalalabad 1	Nangarhar	Khowgiani, Surkh Rod, Chaparhar	15 km
Jalalabad 2	Laghman, Nangarhar	Carghayi, Behsud, Sukh Rod	25 km
Kandahar 1	Kandahar	Maywand, Zheray, Arghandab	15 km
Kandahar 2	Kandahar	Kandahar, Daman, Shah Wali Kot, Arghandab	10 km
Herat 1	Herat	Injil, Karukh	40 km
Herat 2	Herat	Herat, Injil, Karukh	10 km
Mazar 1	Balkh	Deh Dadi, Chemtal,Nahr-e-Shahi	10 km
Mazar 2	Balkh	Nahr-e-Shahi	10 km

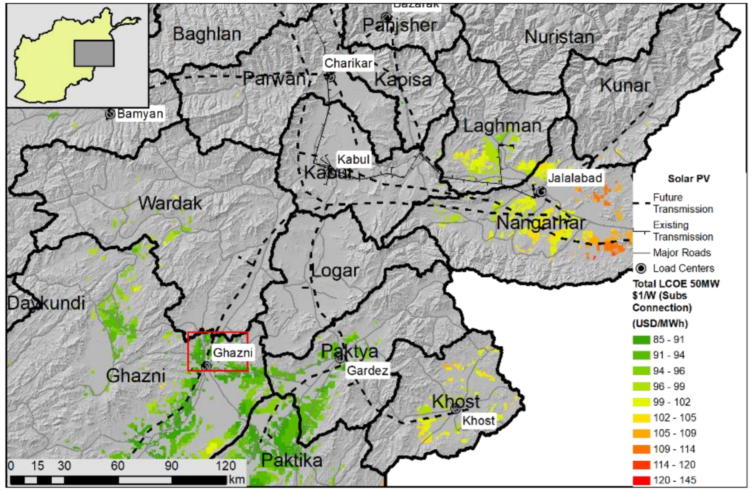
Simulations targeted to potential installation with a capacity of up to 50 MW.

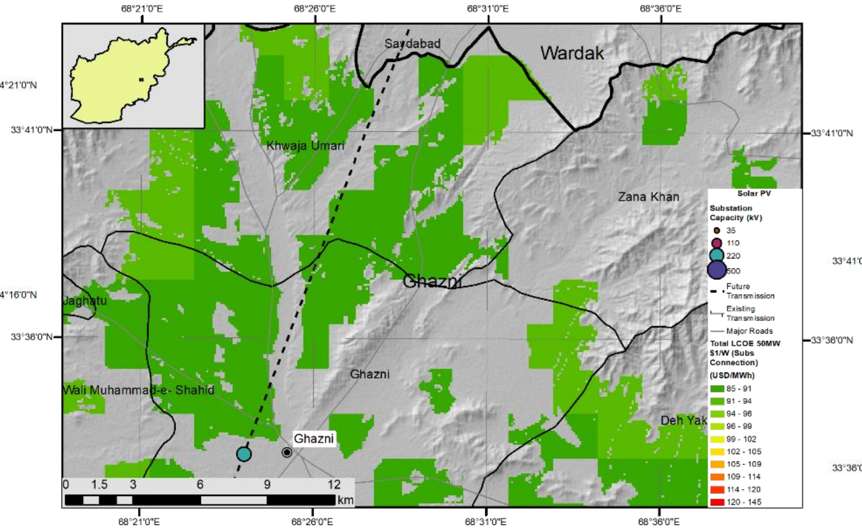
The exact coordinates of each site are reported in the maps.

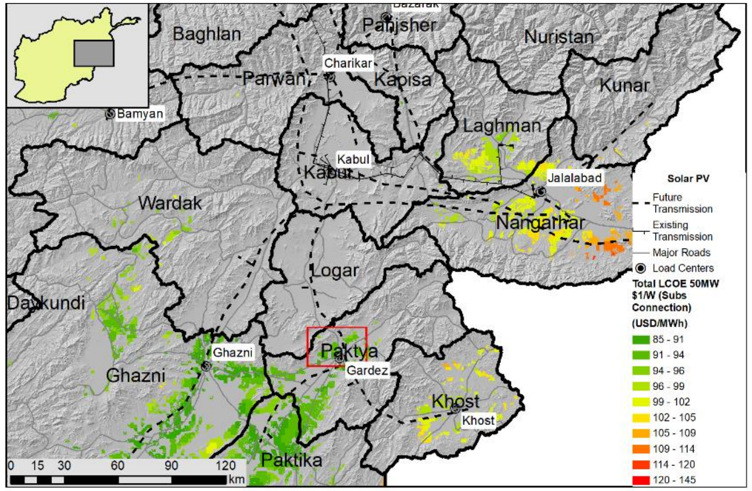
Kabul 1, Kabul 2, Kabul 3

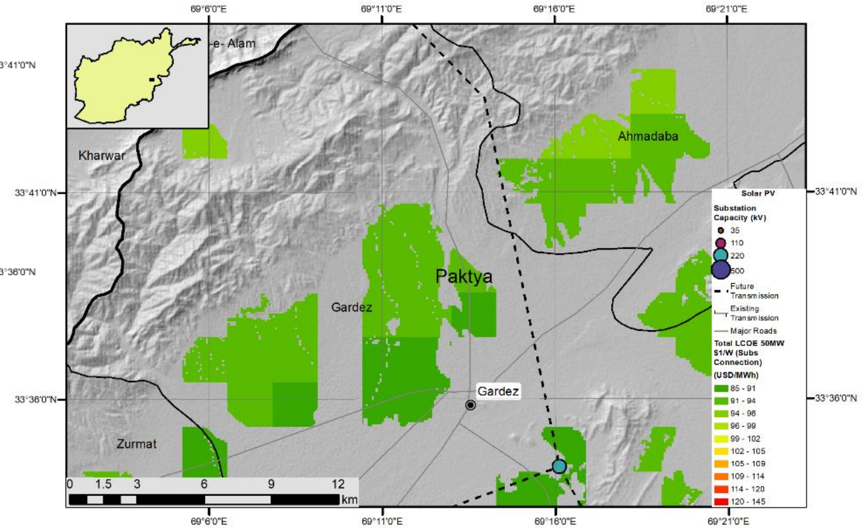




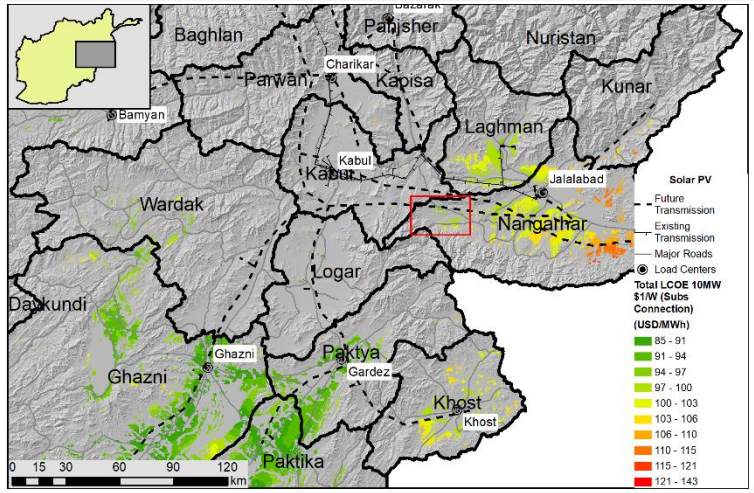


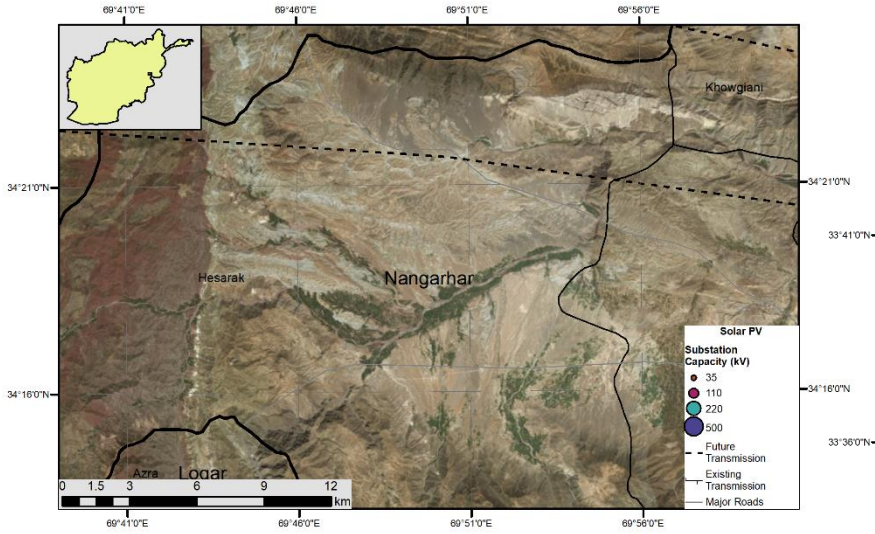


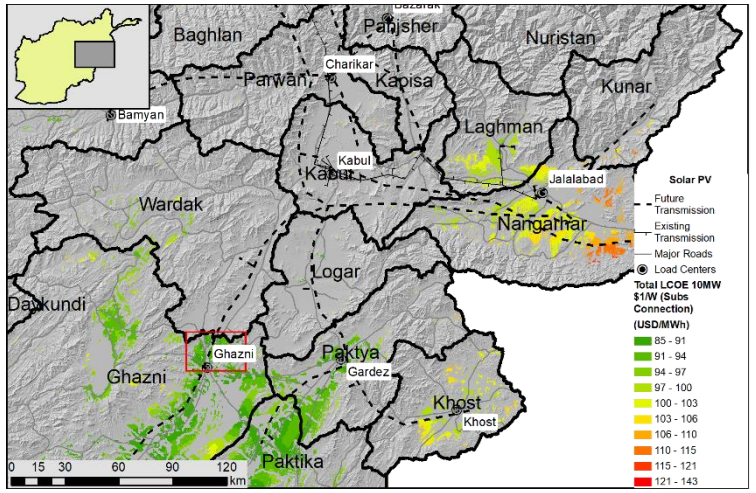


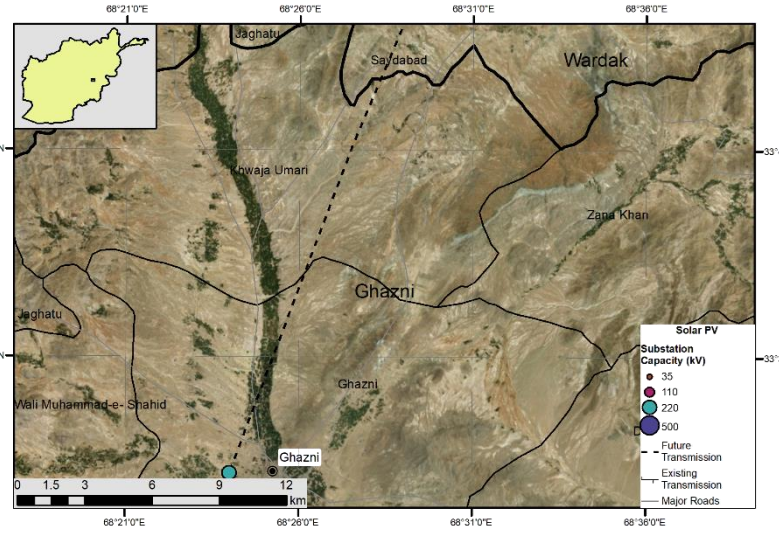


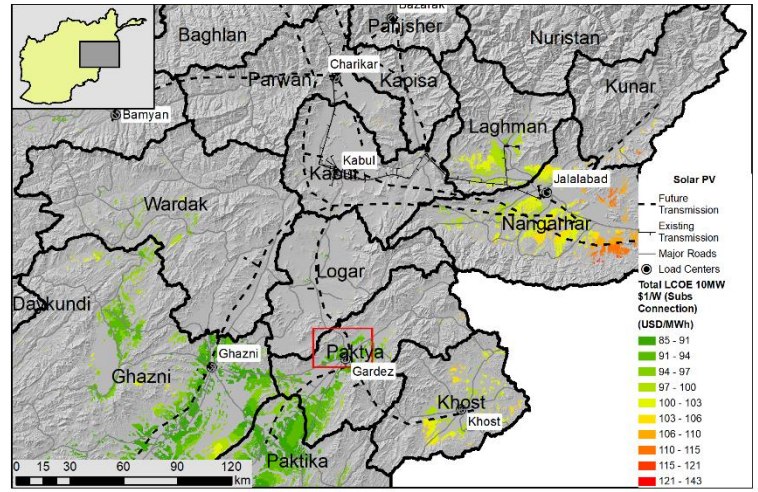
Kabul 1, Kabul 2, Kabul 3 – Satellite Images

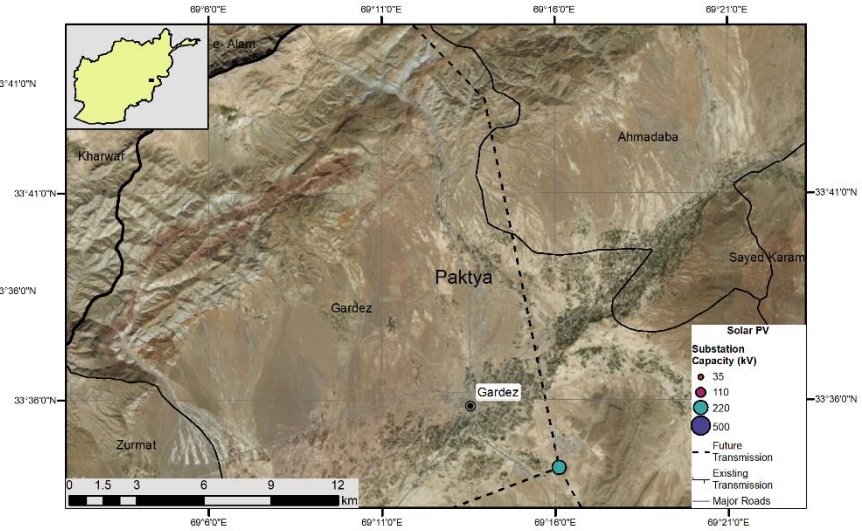




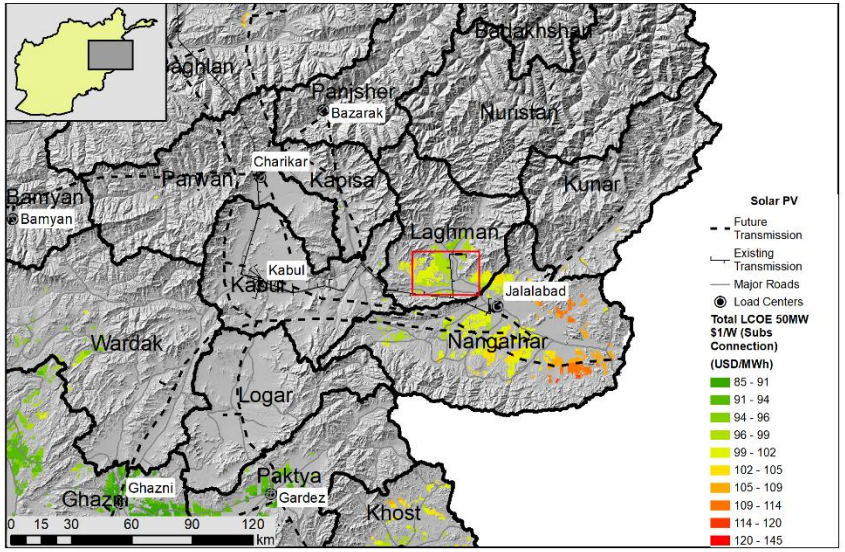


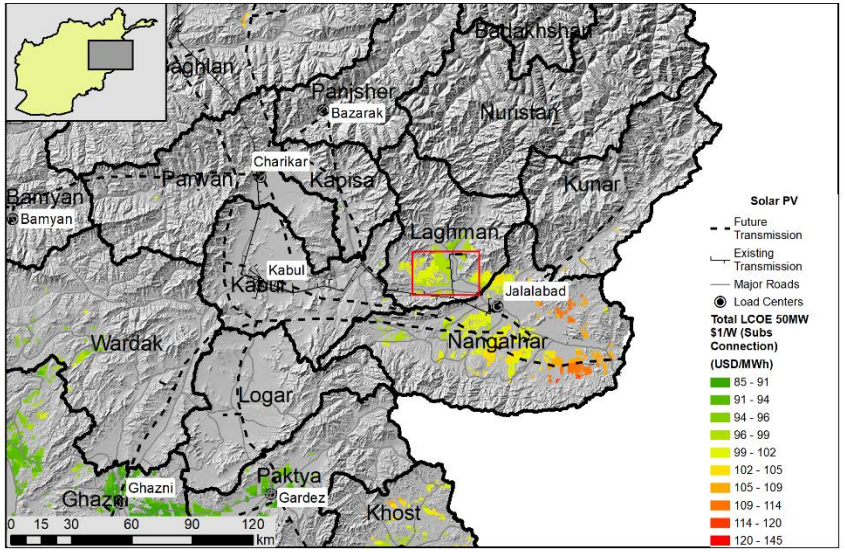


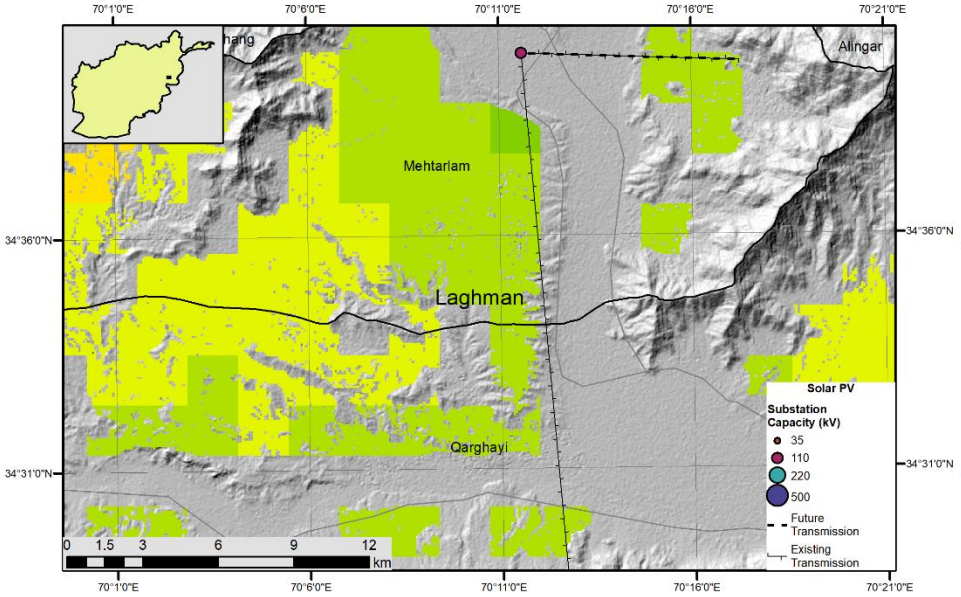


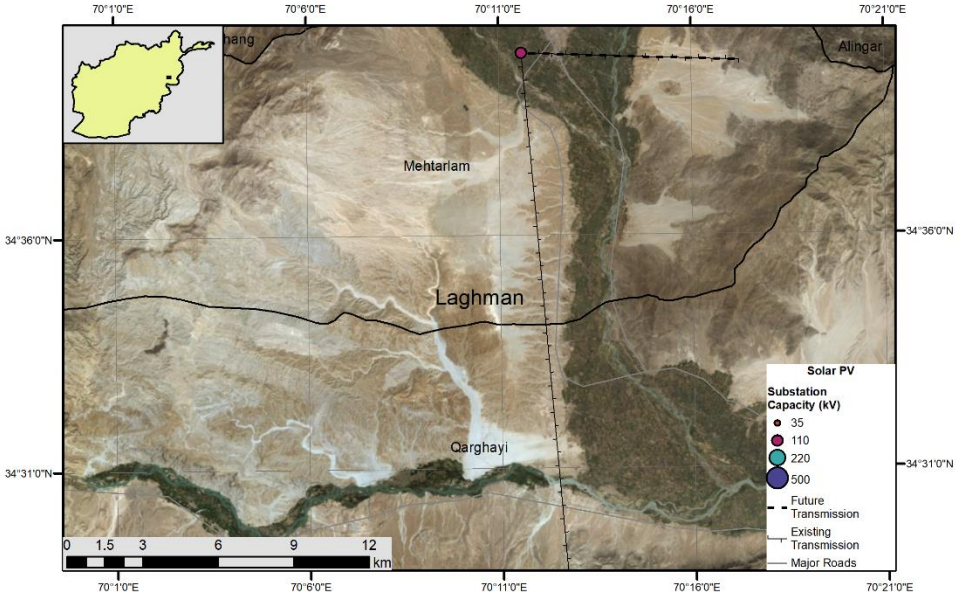


Kabul 4 – Surveyed Site

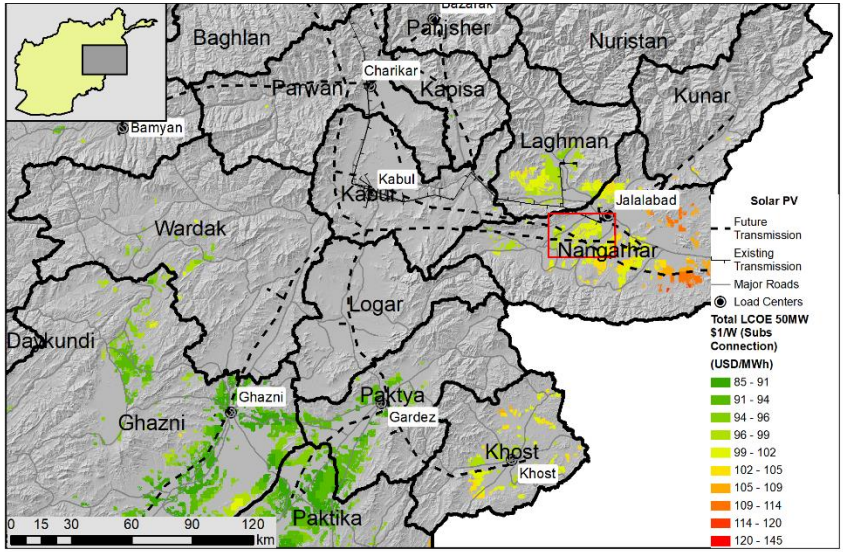








Jalalabad 1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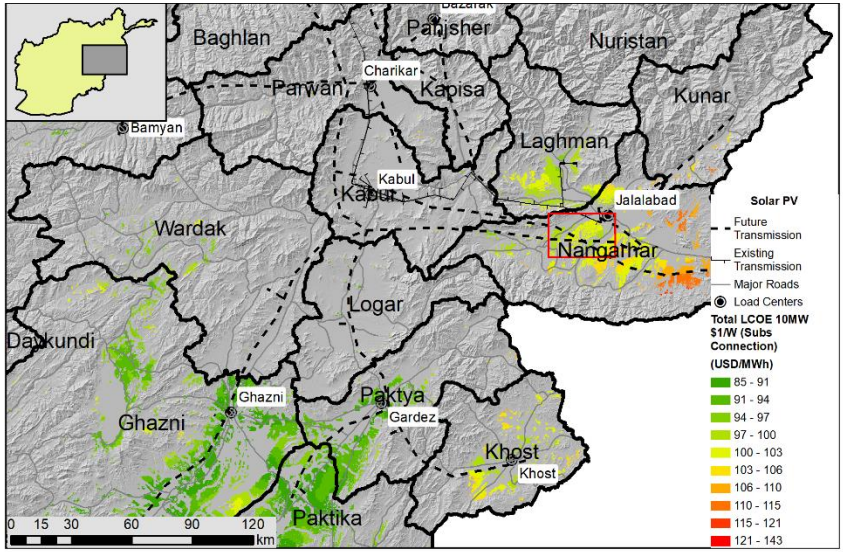
Panjsher
Nuristan
Charikar
Parwan
Kapisa
Kunar
Bamyan
Laghman
Kabul
Jalalabad
Wardak
Nangarhar
Logar
Daikundi
Ghazni
Paktya
Gardez
Khost
Paktika
0 15 30 60 90 120 km
Solar PV
Future Transmission
Existing Transmission
Major Roads
Load Centers
Total LCOE 50MW $1/W (Subs Connection)
(USD/MWh)
85 - 91
91 - 94
94 - 96
96 - 99
99 - 102
102 - 105
105 - 109
109 - 114
114 - 120
120 - 145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Total LCOE 10MW $1/W (Subs Connection)
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85 - 91
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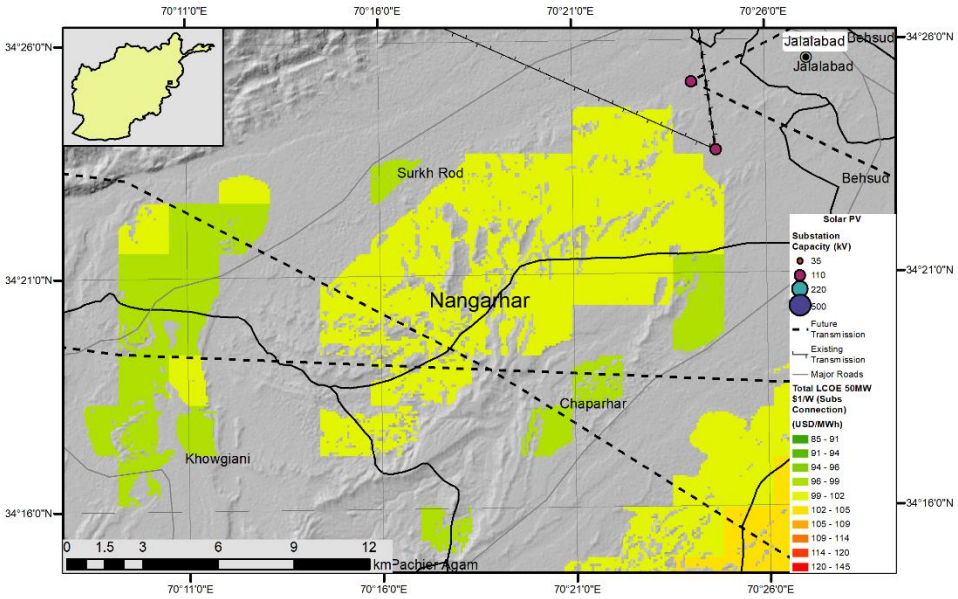
103 - 106
106 - 110
110 - 115
115 - 121
121 - 143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Behsud
Surkh Rod
Nangarhar
Chaparhar
Khowgiani
Pachier Agam
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Solar PV
Substation Capacity (kV)
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Future Transmission
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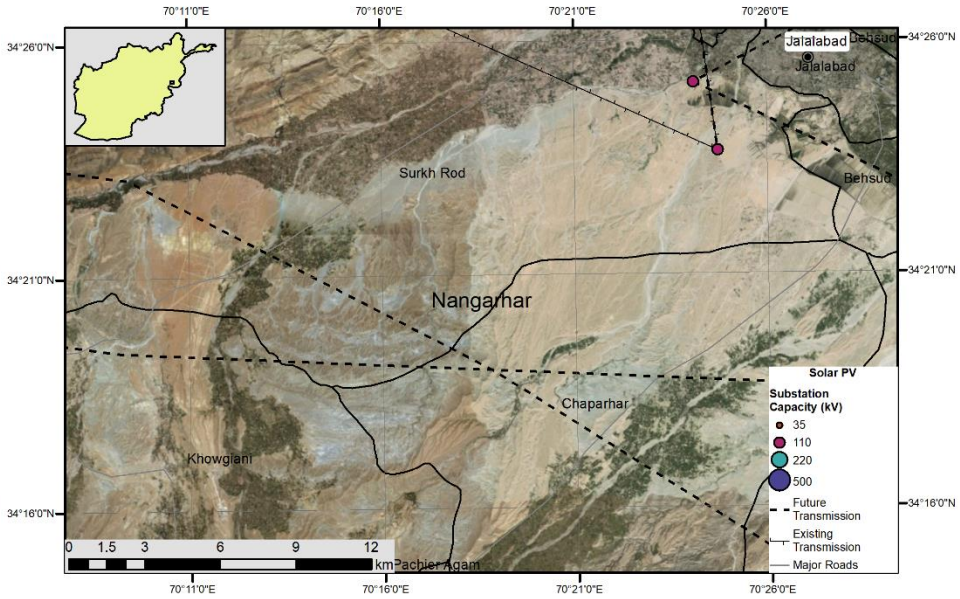
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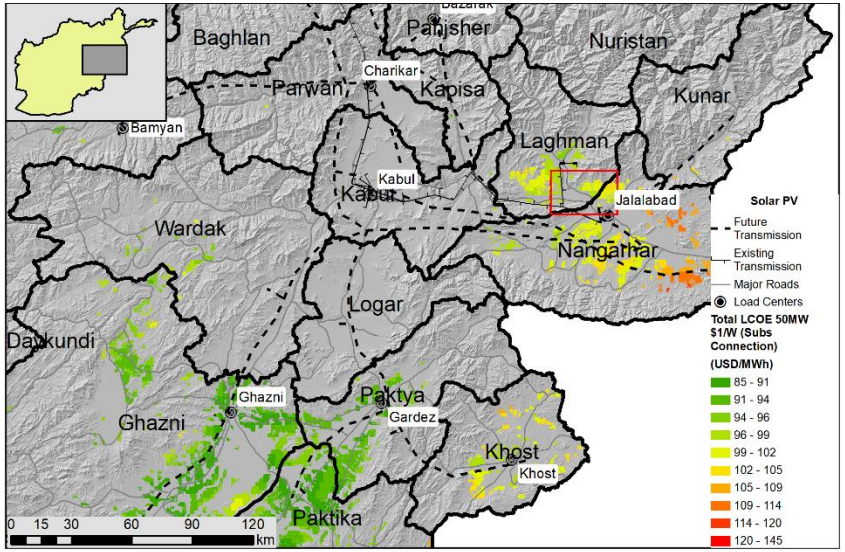
Jalalabad 2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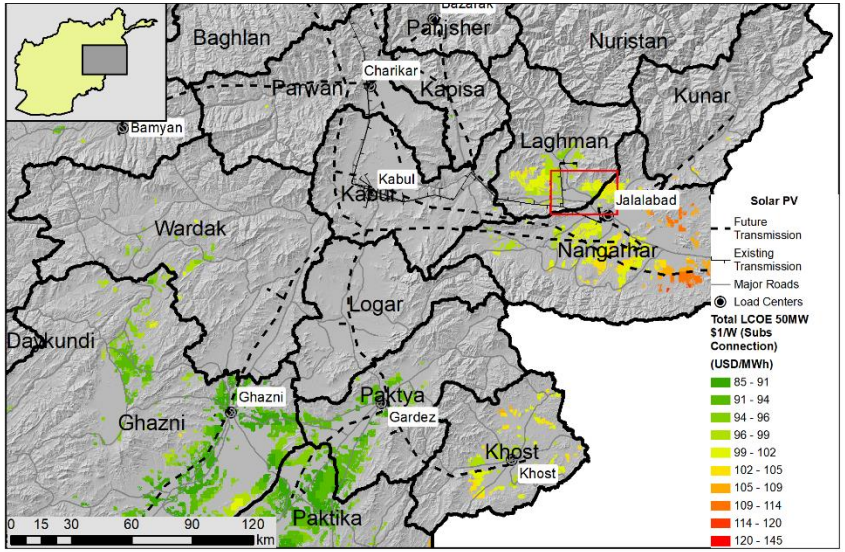
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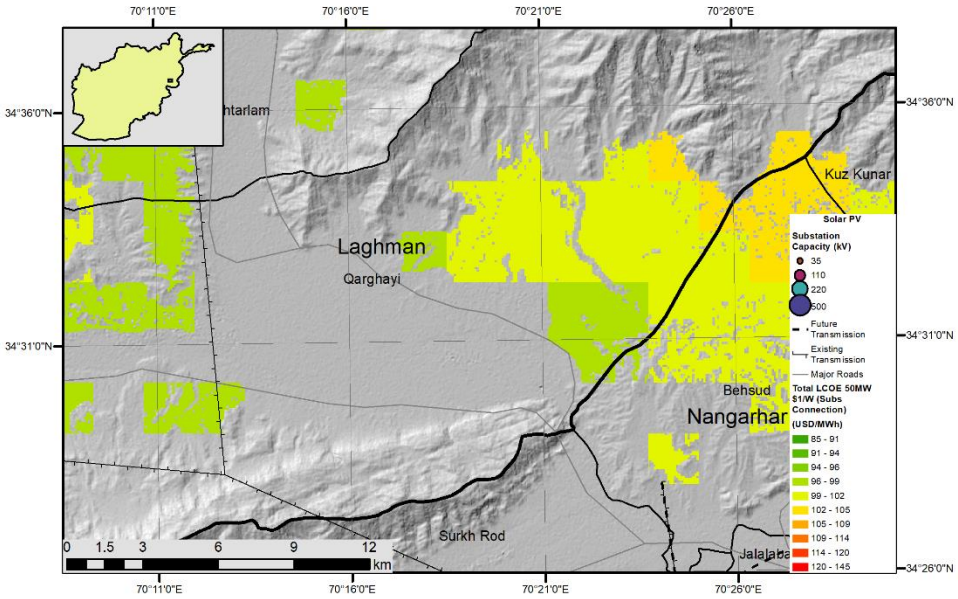
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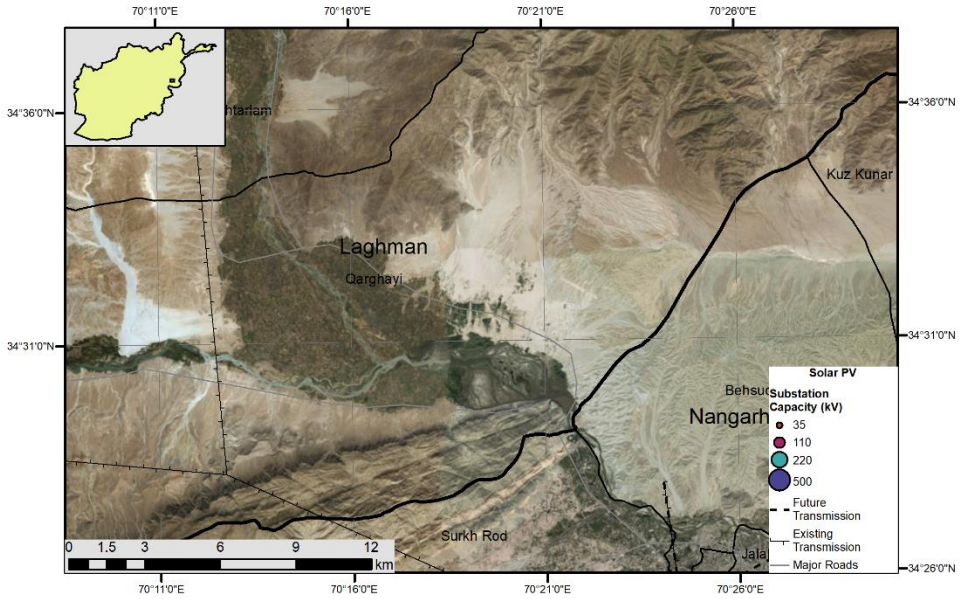
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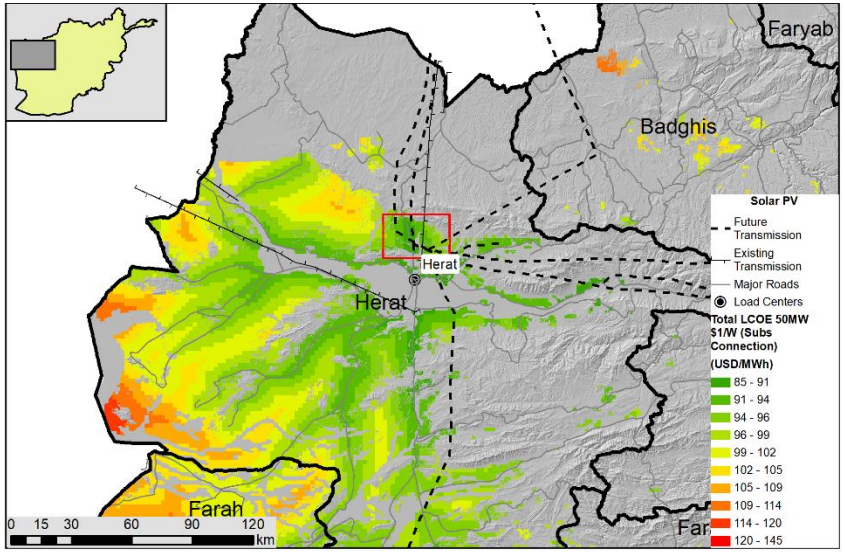
km
Solar PV
Substation Capacity (kV)
35
110
220
500
Future Transmission
Existing Transmission
Major Roads

Herat 1


Faryab
Badghis
Herat
Herat
Farah
Solar PV
Future Transmission
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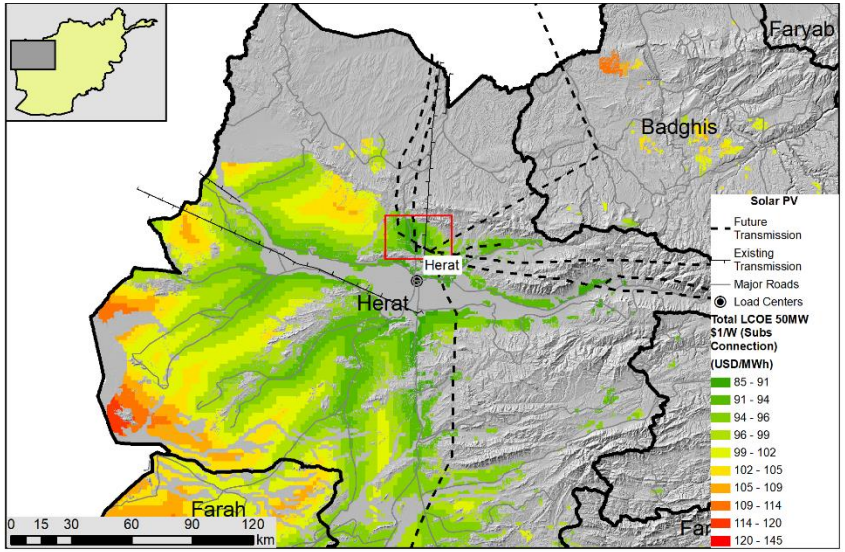
km


Faryab
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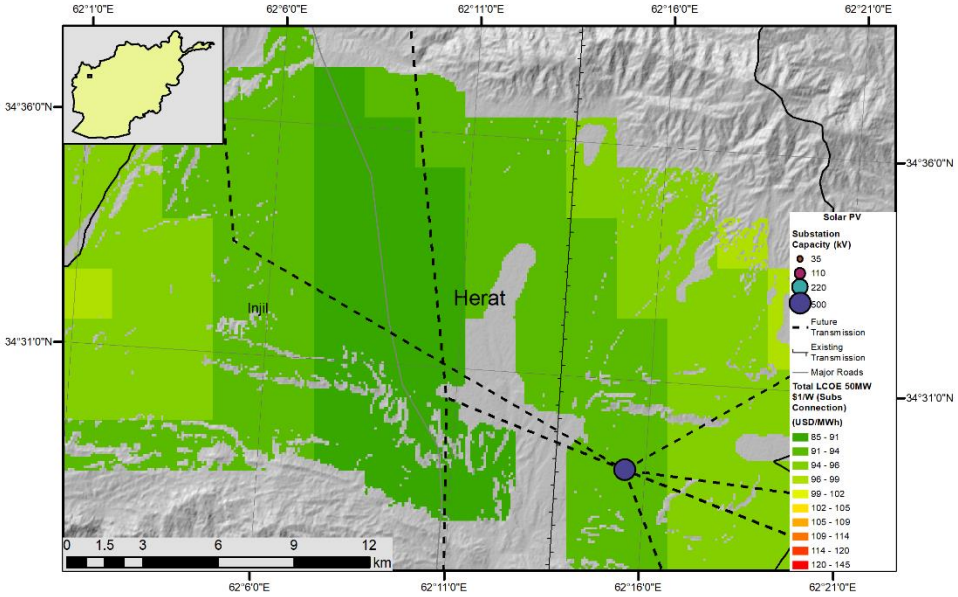
0 15 30 60 90 120
km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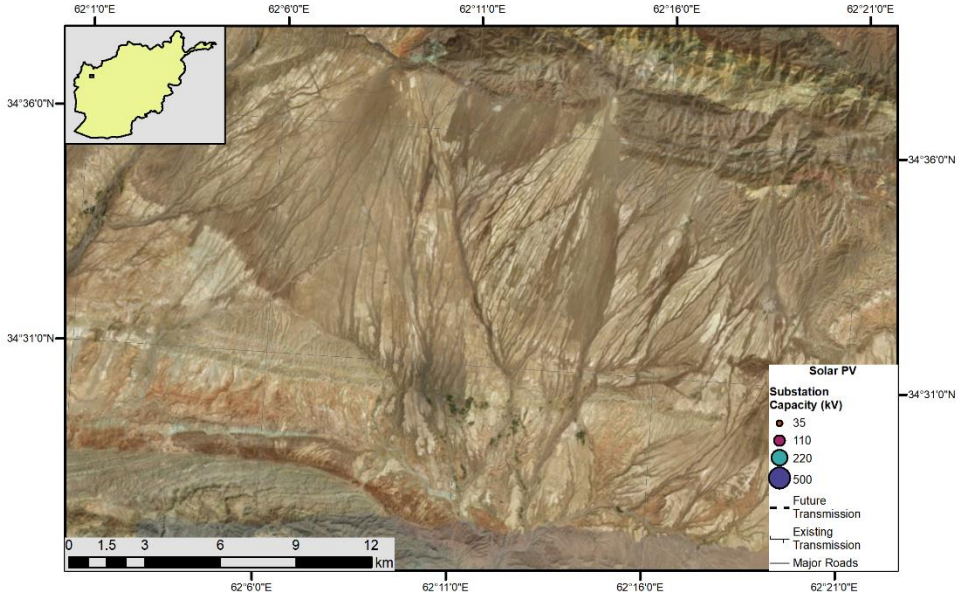
34°31'0"N
Herat
Injil
Solar PV
Substation Capacity (kV)
35
110
220
500
Future Transmission
Existing Transmission
Major Roads
Total LCOE 50MW $1/W (Subs Connection)
(USD/MWh)
85 - 91
91 - 94
94 - 96
96 - 99
99 - 102
102 - 105
105 - 109
109 - 114
114 - 120
120 - 145
0 1.5 3 6 9 12
km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Solar PV
Substation Capacity (kV)
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Future Transmission
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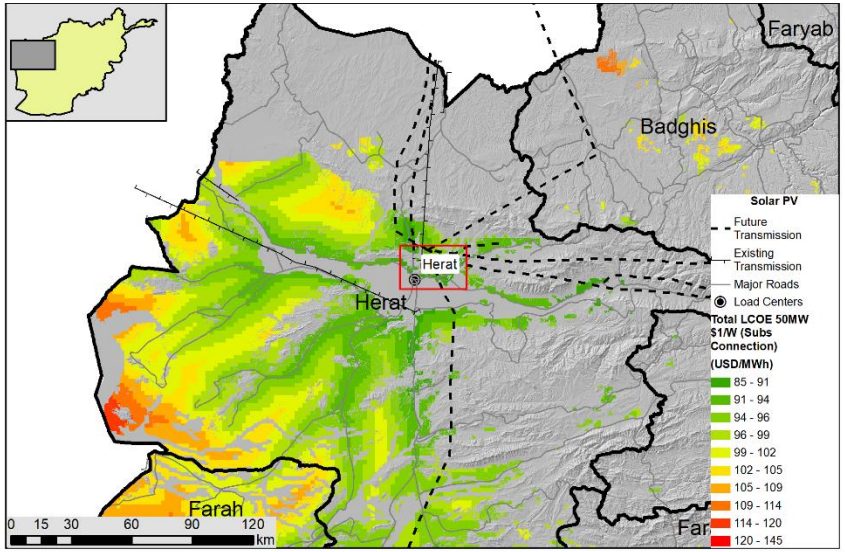
0 1.5 3 6 9 12
km

Herat 2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Badghis
Herat
Herat
Farah
Solar PV
Future Transmission
Existing Transmission
Major Roads
Load Centers
Total LCOE 50MW $1/W (Subs Connection)
(USD/MWh)
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109 - 114
114 - 120
120 - 145
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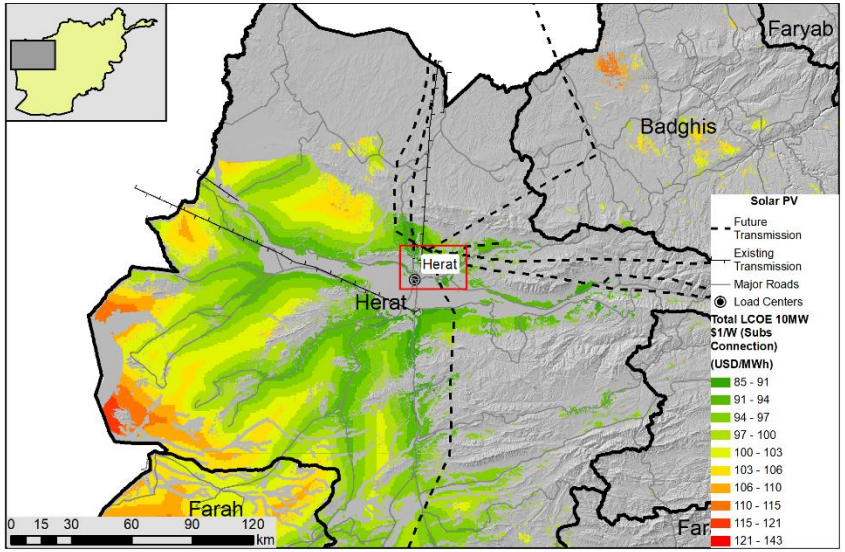
km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Farah
Solar PV
Future Transmission
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Load Centers
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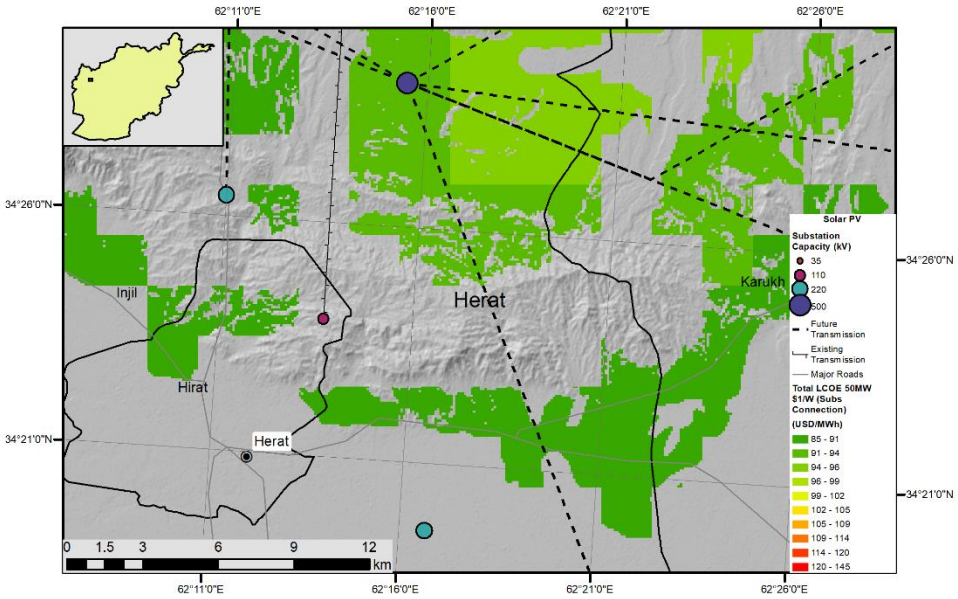
121 - 143
0 15 30 60 90 120
km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Herat
Karukh
Hirat
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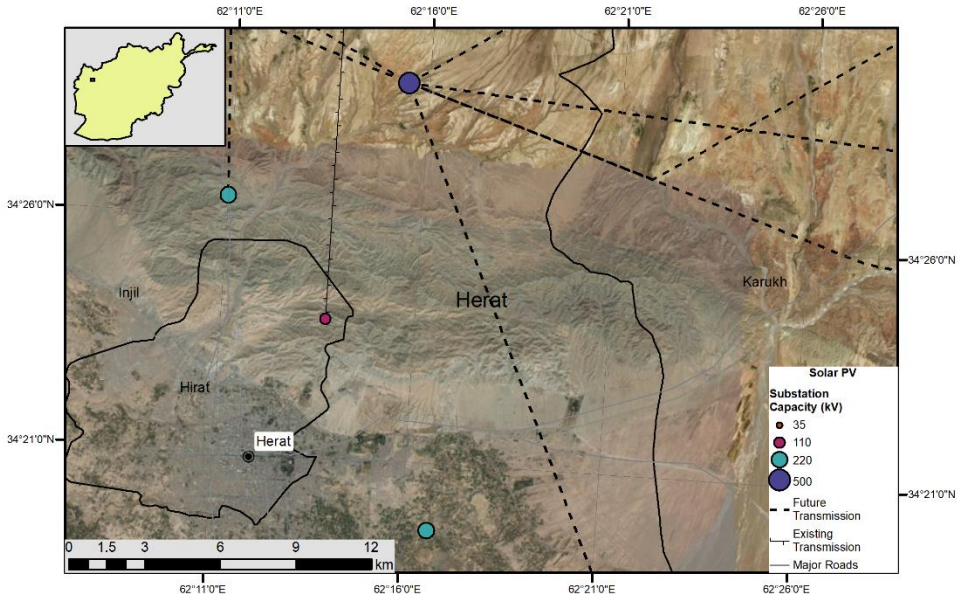
km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Solar PV
Substation Capacity (kV)
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220
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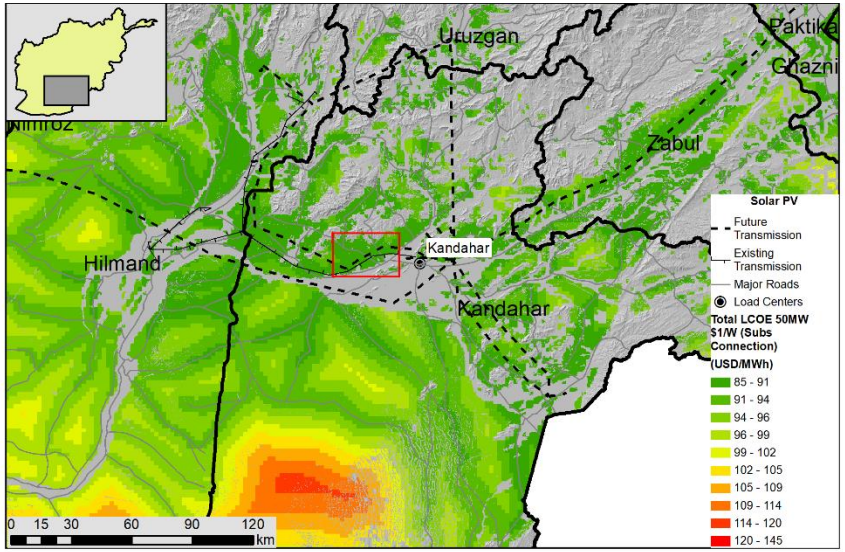
Future Transmission
Existing Transmission
Major Roads
0 1.5 3 6 9 12
km

Kandahar 1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Ghazni
Nimroz
Zabul
Hilmand
Kandahar
Kandahar
Solar PV
Future Transmission
Existing Transmission
Major Roads
Load Centers
Total LCOE 50MW $1/W (Subs Connection) (USD/MWh)
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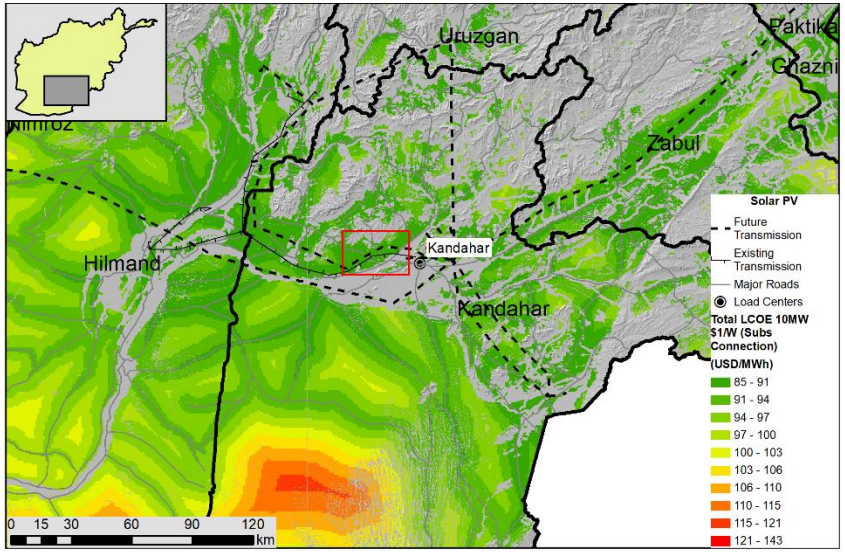
105 - 109
109 - 114
114 - 120
120 - 145
0 15 30 60 90 120 km


Uruzgan
Paktika
Ghazni
Nimroz
Zabul
Hilmand
Kandahar
Kandahar
Solar PV
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Existing Transmission
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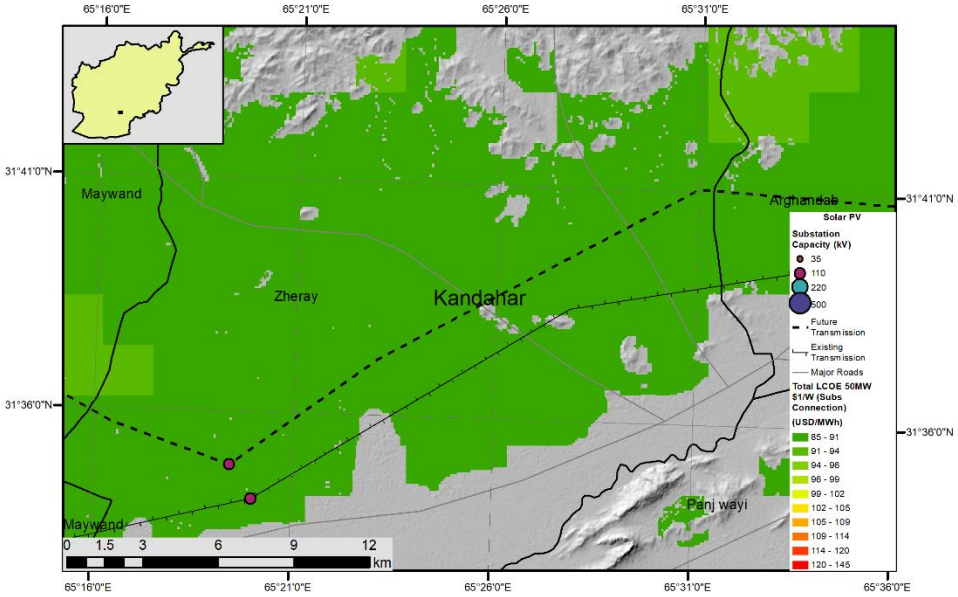
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31°41'0"N
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Maywand
Arghandab
Zheray
Kandahar
Panj wayi
Solar PV
Substation Capacity (kV)
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110
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500
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Existing Transmission
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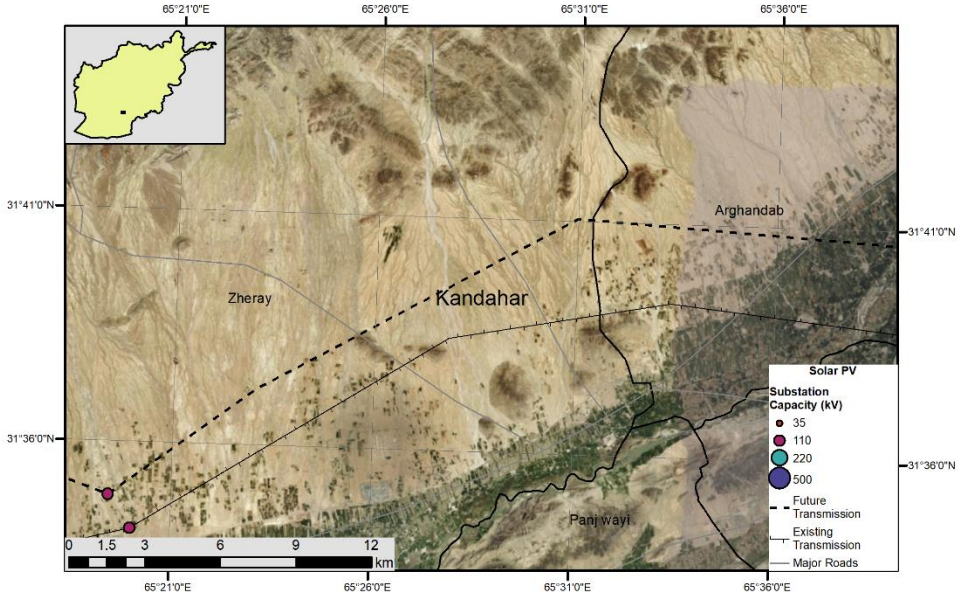
105 - 109
109 - 114
114 - 120
120 - 145
0 1.5 3 6 9 12 km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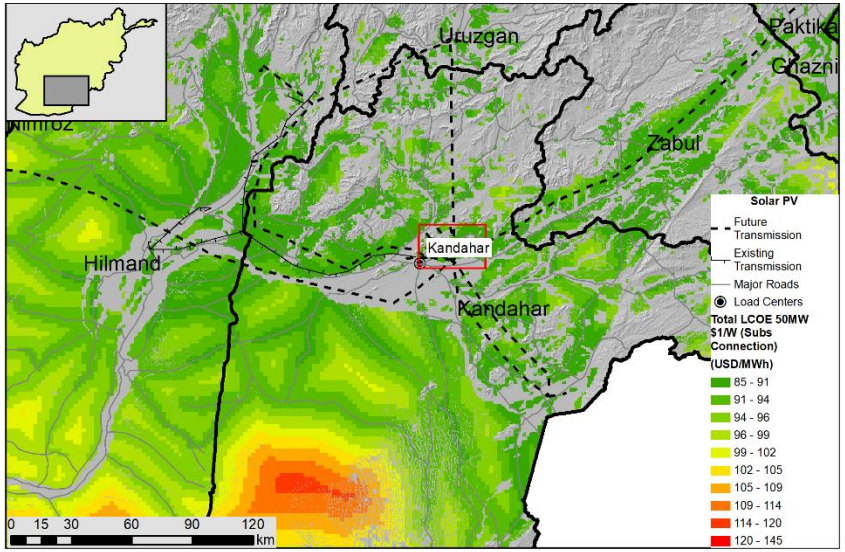
Arghandab
Zheray
Kandahar
Panj wayi
Solar PV
Substation Capacity (kV)
35
110
220
500
Future Transmission
Existing Transmission
Major Roads
0 1.5 3 6 9 12 km

Kandahar 2


Uruzgan
Paktika
Ghazni
Zabul
Hilmand
Kandahar
Kandahar
Solar PV
Future Transmission
Existing Transmission
Major Roads
Load Centers
Total LCOE 50MW $1/W (Subs Connection) (USD/MWh)
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91 - 94
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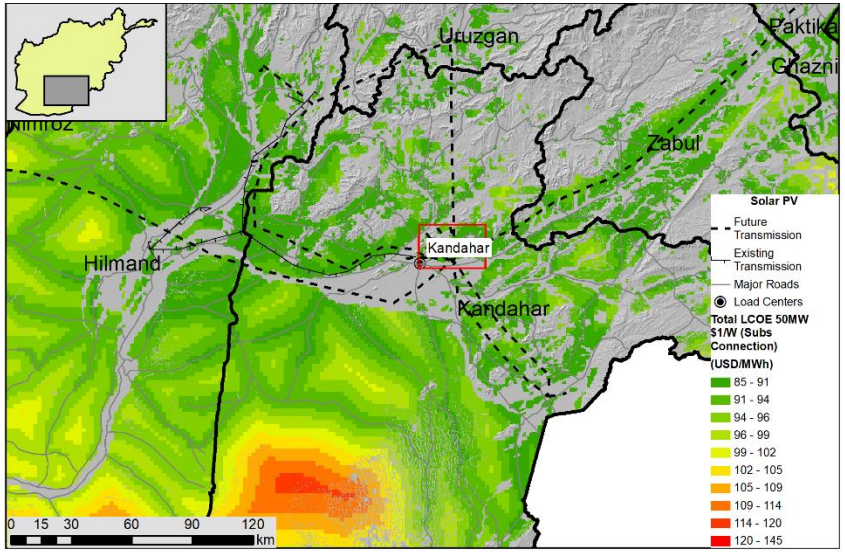
99 - 102
102 - 105
105 - 109
109 - 114
114 - 120
120 - 145
0 15 30 60 90 120 km


Uruzgan
Paktika
Ghazni
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Hilmand
Kandahar
Kandahar
Solar PV
Future Transmission
Existing Transmission
Major Roads
Load Centers
Total LCOE 50MW $1/W (Subs Connection) (USD/MWh)
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91 - 94
94 - 96
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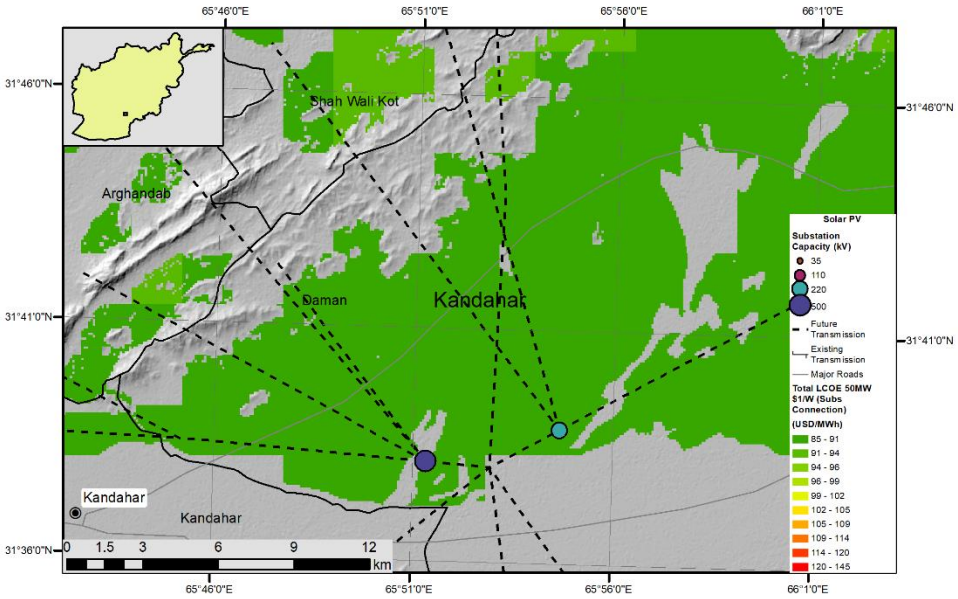
105 - 109
109 - 114
114 - 120
120 - 145
0 15 30 60 90 120 km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Shah Wali Kot
Arghandab
Daman
Kandahar
Kandahar
Kandahar
Solar PV
Substation Capacity (kV)
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110
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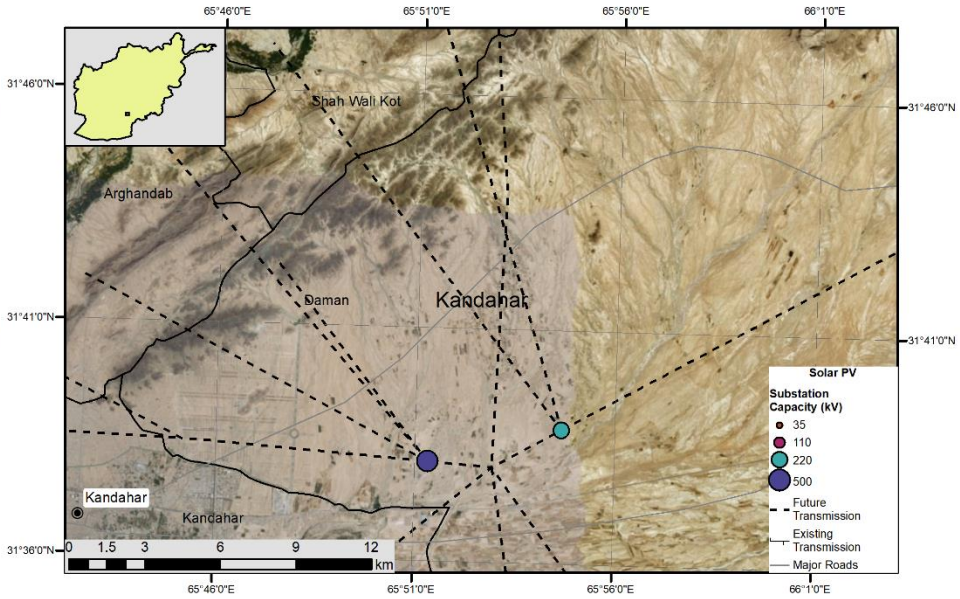
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Kandahar
Solar PV
Substation Capacity (kV)
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Future Transmission
Existing Transmission
Major Roads
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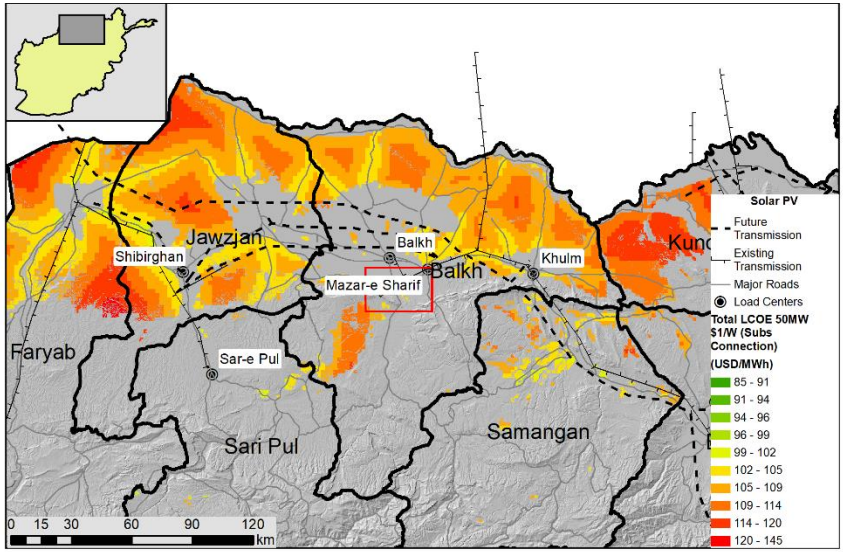
Mazar 1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Balkh
Balkh
Khulm
Mazar-e Sharif
Faryab
Sar-e Pul
Sari Pul
Samangan
Solar PV
Future Transmission
Existing Transmission
Major Roads
Load Centers
Total LCOE 50MW $1/W (Subs Connection)
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85 - 91
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114 - 120
120 - 145
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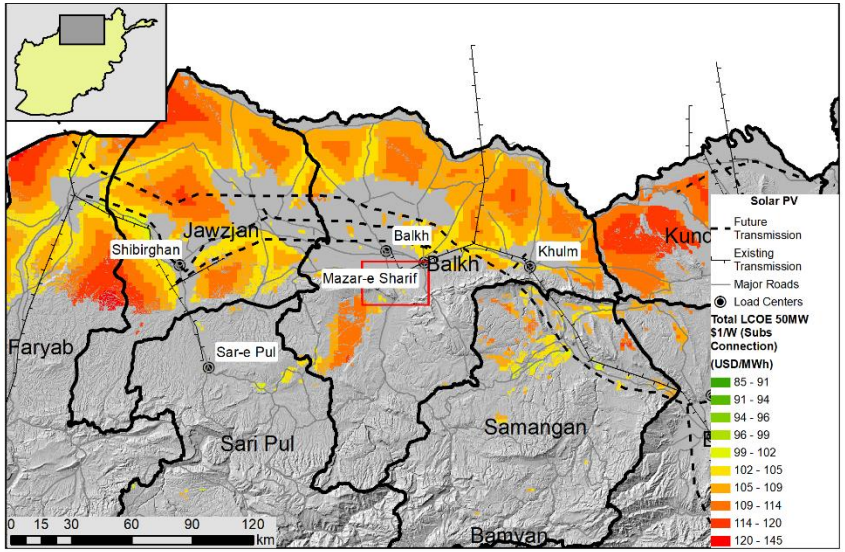
km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Balkh
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Khulm
Mazar-e Sharif
Faryab
Sar-e Pul
Sari Pul
Samangan
Bamyan
Solar PV
Future Transmission
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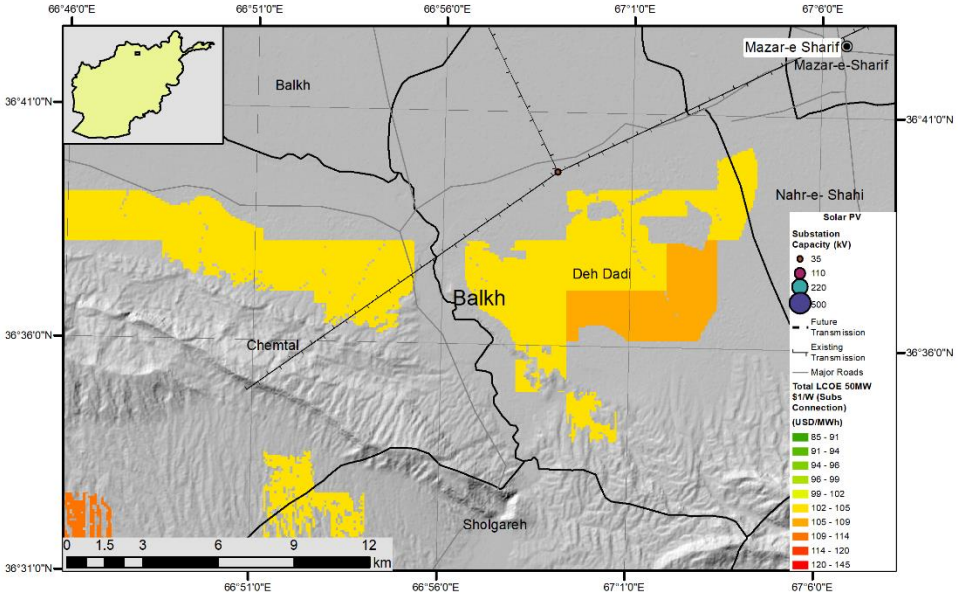
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Mazar-e Sharif
Mazar-e-Sharif
Balkh
Nahr-e- Shahi
Deh Dadi
Balkh
Chemtal
Sholgareh
Solar PV
Substation Capacity (kV)
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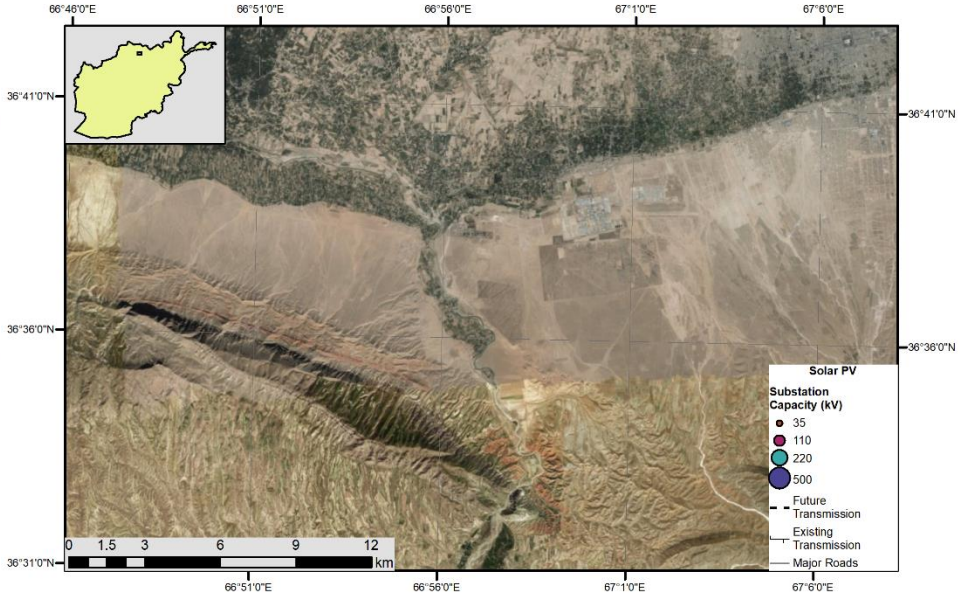
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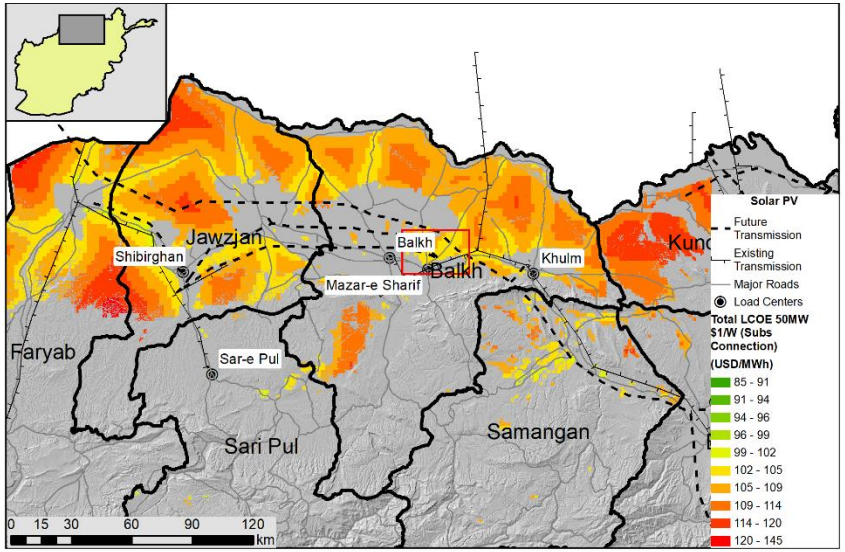
km

Mazar 2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Mazar-e Sharif
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Sar-e Pul
Sari Pul
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Solar PV
Future Transmission
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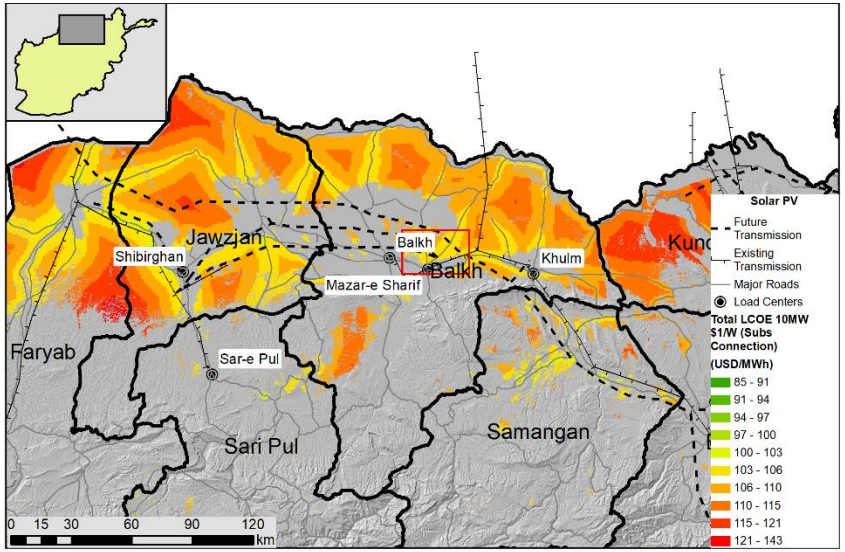
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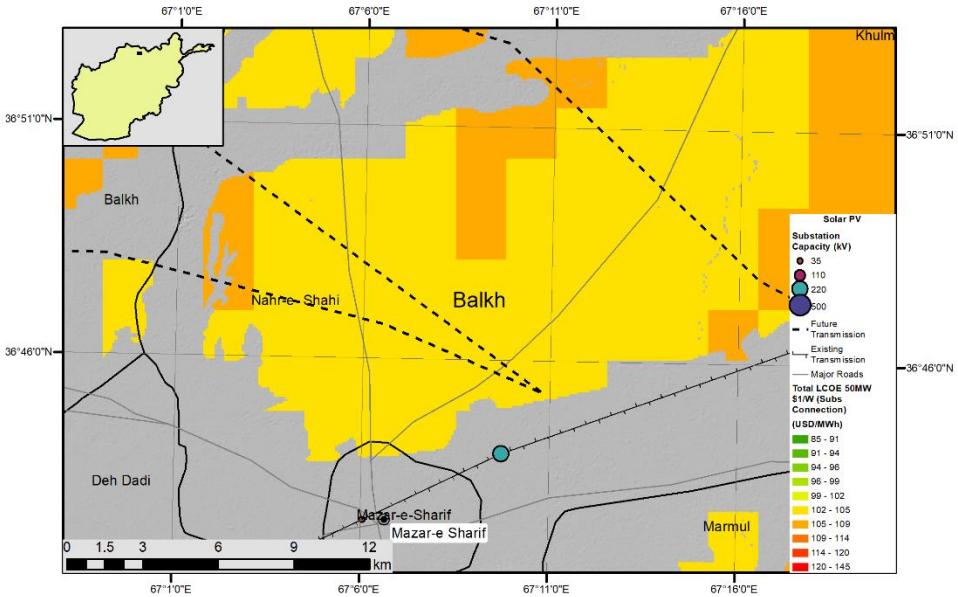
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Balkh
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Mazar-e Sharif
Marmul
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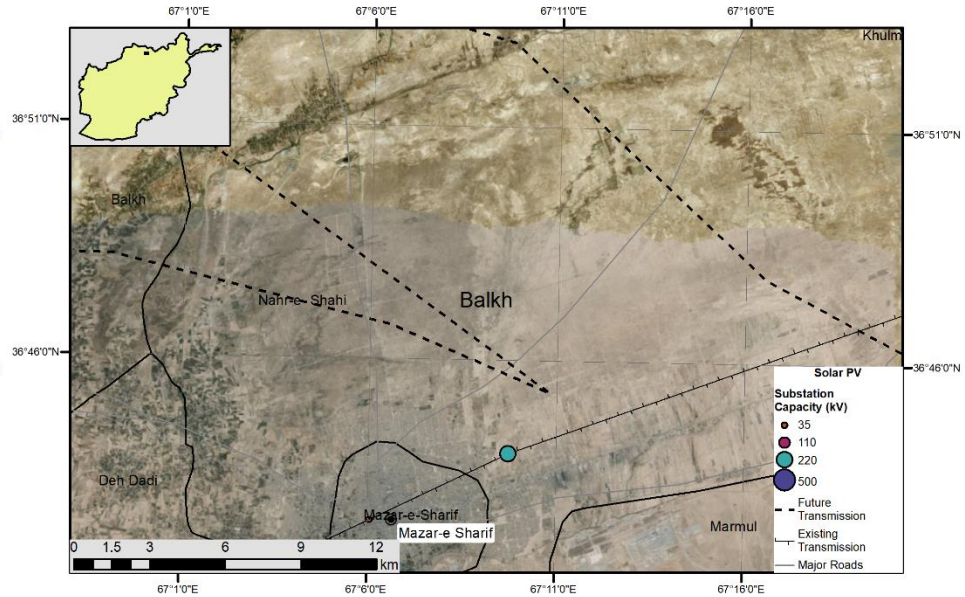
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Marmul
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Data Gaps and Next Steps

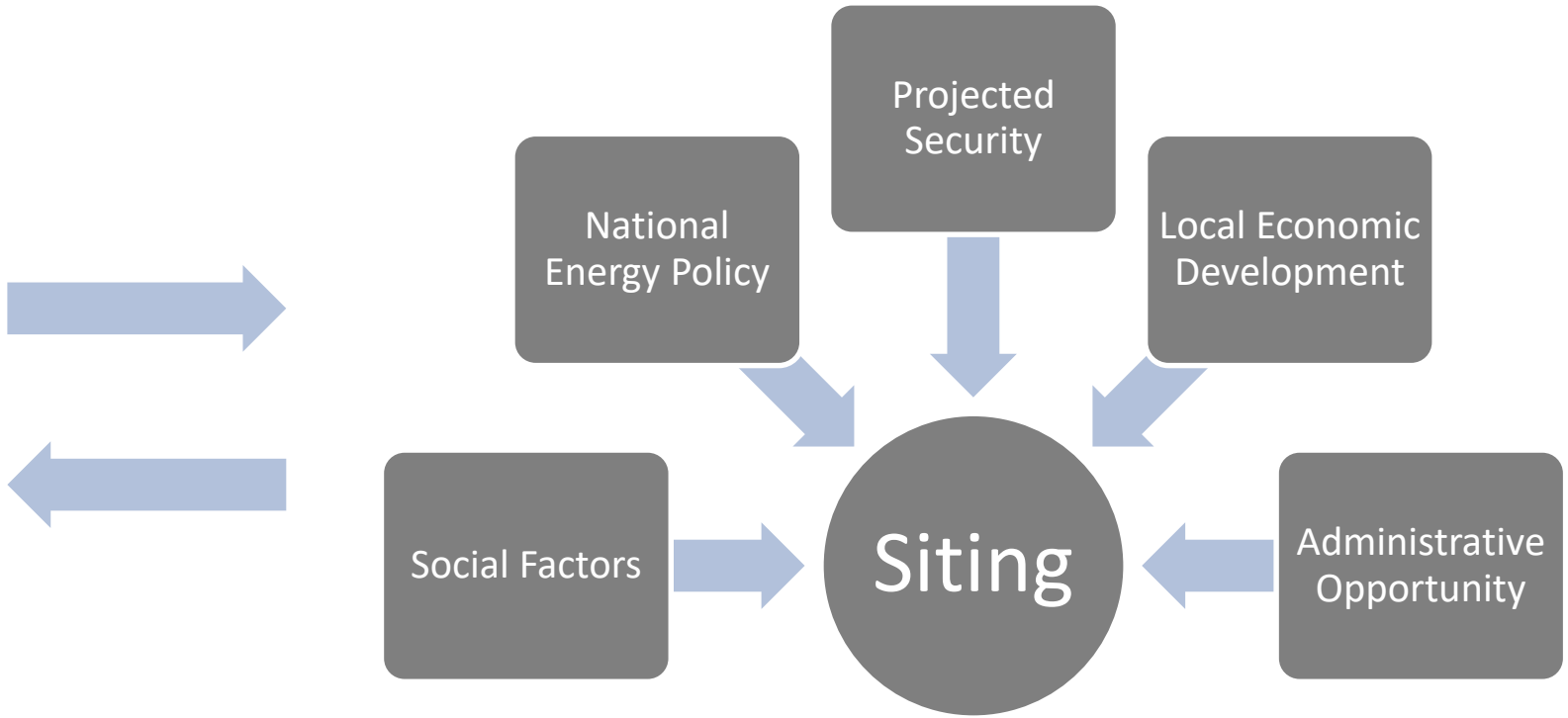
Missing data

- Land ownership
- Security
- Heritage

Detailed Geospatial Analysis

Feasibility Study

- Geological analysis
- Hydrology analysis
- Site visit



Acknowledgements

The multi-criteria analysis benefitted from guidance and inputs from Ministry of Energy and Water (MEW), Da Afghanistan Breshna Sherkat (DABS), Capital Region Independent Development Authority (CRIDA), Arazi, and the Ministry of Agriculture, Irrigation and Livestock (MAIL).

MEW	Haider Mohsini
	Zahra Rasooli
	Asif Ibrahimi
DABS	Safiullah Faqirzay
	Esmat Sharif
CRIDA	Farhad Miakhel
Arazi	Mohammad Arif Yaqubi
	Ahmad Fawad
	Zabiullah Rahmati
	Zaher Sultani
MAIL	Mohammad Asif Akbari
WBG	Taiba Jafari
	M. Zubair Stanikzai
	Abdul Baes Akhundzada

Thank you