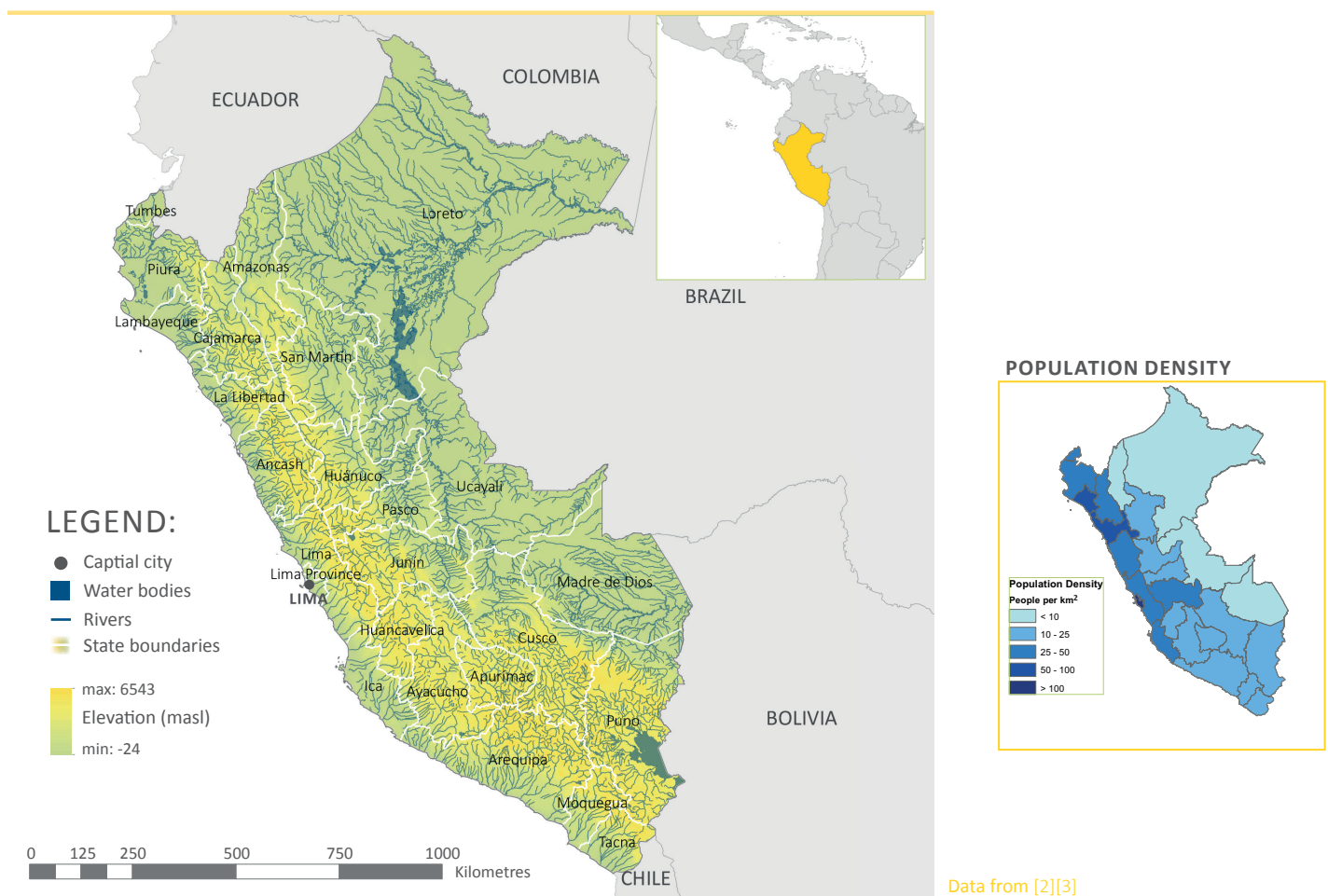# Peru

Document elaborated in August 2018

The Water-Energy-Food Security Nexus Country Profile

Peru is located from 0°S to 18°S in western South America; it borders Ecuador and Colombia to the north, Brazil to the east, Bolivia to the southeast, Chile to the south, and the Pacific Ocean to the west. Three contrasting geographic regions exist in the country [1]:

- Coastal region: a long, desertic plain with a very dry climate. The region stretches along the coast on the west of the country and is approximately 50-100 km wide.

- The highlands: the mountainous region running down the middle of the country, with the majority of the land at an elevation of above 3000 m and well defined wet and dry seasons.

- The Amazon rainforest: a warm and humid tropical climate located to the east of the mountain range. Most of the area is covered in impenetrable rainforest.

LEGEND:
- Captial city
- Water bodies
- Rivers
- State boundaries

max: 6543
Elevation (masl)
min: -24

0 125 250 500 750 1000
Kilometres

POPULATION DENSITY

Population Density
People per km²
< 10
10 - 25
25 - 50
50 - 100
> 100

Data from [2][3]

Highlighted Nexus-related challenges faced by Peru:

- Water scarcity in the highly-populated coastal region:
  - The coastal region (including Lima) is extremely dry, yet most of the population and economic activities are centred there [4].
  - Extremely high water demand from agriculture coupled with low irrigation efficiencies [5].
  - The Ministry of housing, Construction and Sanitation plans to build numerous desalination plants to ensure the drinking water supply [6].

- Non-diversified energy mix and high dependency on water availability (hydropower): Peru aims to have a 60% renewable energy mix by 2025 [7].

- Food security, especially in terms of food accessibility, is classified as low in the country [8]
  - The high Andean areas are extremely vulnerable to climate change [9], threatening food production in these areas.

GENERAL INFORMATION

1,285,200 km² Size [10]

31,774,000 Population (2016)[10]

1.3% Population growth
annual (2016)[10]

78.9% Urban Population (2016)[10]

192 billion US$ Total GDP (2016)[10]

5,950 US$ GNI per capita[i] (2016)
World average: 10,308 [10]

3.0% Poverty headcount ratio at $1.90 a day (2015)[10]

44.3 Gini coefficient[ii] (2015)[10]
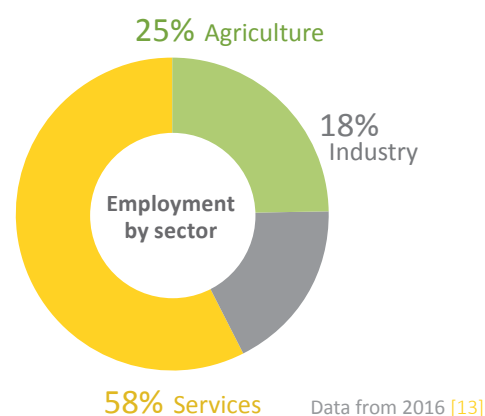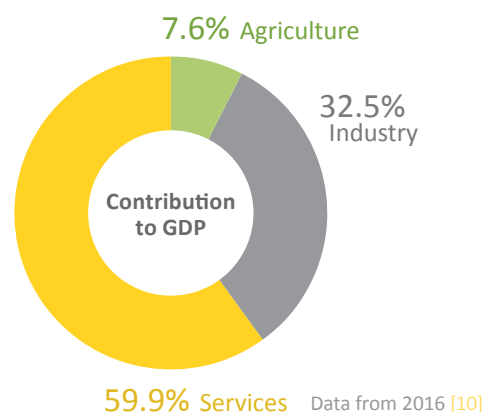*Ranked the 39th most unequal of 158 countries rated* [11]

0.740 HDI[iii] (2015)
Ranked 66th of 188 countries rated [12]
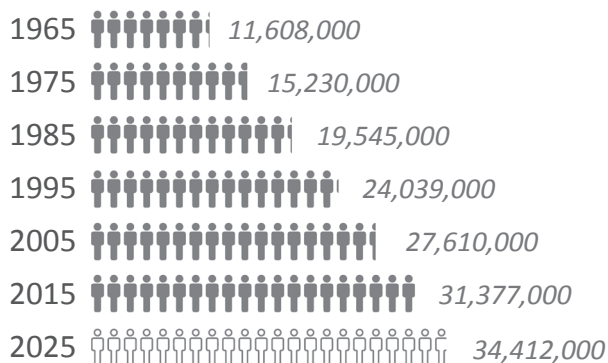
94.1% School Enrolment, Primary (2015)[10]

94.2 % Literacy rate (over 15) (2016)[10]

74.7 years Life expectancy (2015)[10]

11.9 per 1000 births Infant mortality rate (2016)[10]

Contribution to GDP

7.6% Agriculture
32.5% Industry
59.9% Services
Data from 2016 [10]

Employment by sector

25% Agriculture
18% Industry
58% Services
Data from 2016 [13]

Population growth

Year	Population
1965	*11,608,000*
1975	*15,230,000*
1985	*19,545,000*
1995	*24,039,000*
2005	*27,610,000*
2015	*31,377,000*
2025	*34,412,000*

Based on data from [10] and [16]

Lima, the capital, has undergone rapid urbanisation in the 20th century, with a large flow of migrants from the provinces [14]. As a result, census results show the population of the province of Lima growing from 830,000 to 8,450,000 from 1940 to 2007 [3]. Lima is now the financial and economic centre of Peru, and more than 50% of the country's GDP is generated in the city [4].

From 2003 to 2013, Peru has been the second fastest growing economy of the Latin America and the Caribbean region [15].

Implementation of the Sustainable Development Goals (SDGs): [17]

- In October 2016, an initial exercise was undertaken by the Peruvian government in order to align sectoral policies with the goals and targets by 2021.
- However, a new round of policy and plan updates is required in order to pursue sustainable development

[i] The gross national income (GNI) is the sum of a nation's gross domestic product and the net income it receives from overseas.
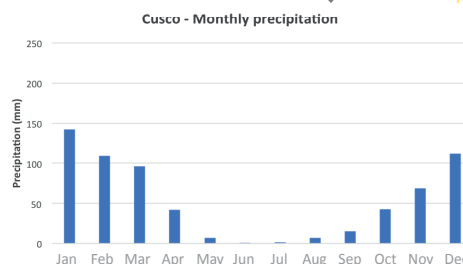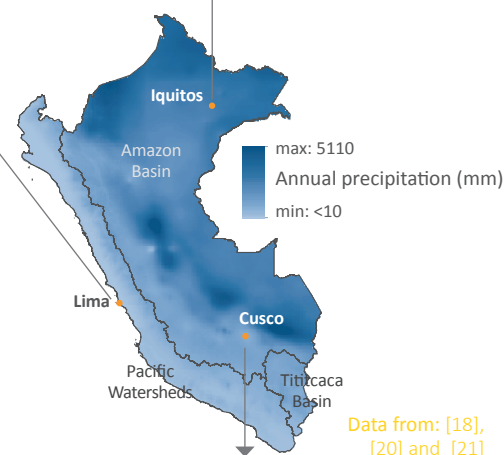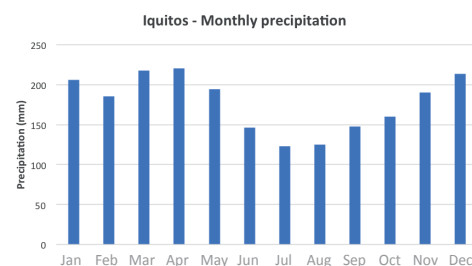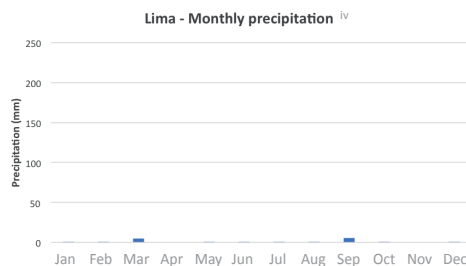
[ii] The Gini coefficient is used as a gauge of economic inequality, measuring income distribution among a population. The coefficient ranges from 0 to 1, with 0 representing perfect equality and 1 representing perfect inequality.

[iii] The Human Development Index (HDI) measures a country's overall achievement in social and economic dimensions, using life expectancy, education and per capita income indicators.

WATER SECTOR

The map below shows that spatial variation of annual mean precipitation, as well as showing a selection of three locations to display monthly fluctuations. Due to the varying water resources availability in different basins as well as the locations of the highly populated areas, it is helpful to divide Peru into three drainage slopes, which is also shown on the map below.

Lima - Monthly precipitation [iv]

Iquitos - Monthly precipitation

max: 5110
Annual precipitation (mm)
min: <10

Data from: [18], [20] and [21]

Cusco - Monthly precipitation

Value	Description
<10 to 5,110 mm	Annual precipitation *(average of 1,520 mm)* [18]
1,641,000 x 10⁶ m³/yr	Internal renewable water resources[v] [1]
61,884 m³/yr	Internal renewable water resources per person [1]
19,100 x 10⁶ m³/yr	Total water consumption (2014) [19]
13%	Water dependency ratio[vi] [1]
86.7 %	Population with access to improved drinking water sources (2015)[10]
76.2 %	Population with access to improved sanitation facilities (2015)[10]
5,770 x 10⁶ m³	Total capacity of dams/reservoirs (2010)[1]

When considering average values at the country level, there appears to be an abundance of water resources. However, there are regions of high water scarcity within Peru, predominantly in the highly-populated Pacific watersheds [4]. 88% of consumptive use of surface water in Peru is for agriculture [19].

A highlighted case of groundwater management is the Ica Valley aquifer. The abstraction rate is significantly higher than the estimated recharge rate, with weak governance allowing private enterprises to over-extract the water resources [22] [23]. Salination has also been identified as a problem in this aquifer [22].

The three identified hydrological regions are the Pacific, the Amazon, and the closed basin of Lake Titicaca. The Amazon watershed accounts for approximately 98% of the country's available surface water, but economic activity is considerably smaller within this watershed [15].
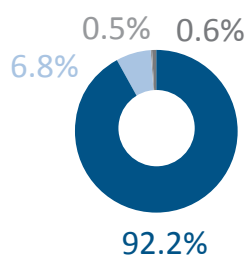
CONSUMPTIVE WATER USES

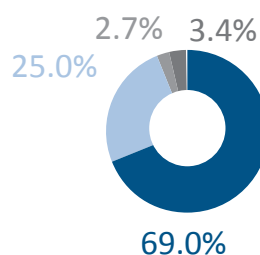### Water extraction by source
Total annual extraction: 13,674 x 10⁶ m³

0.04% Desalination
0.2% Agricultural Drainage
12.9% Groundwater
86.4% Surface Water
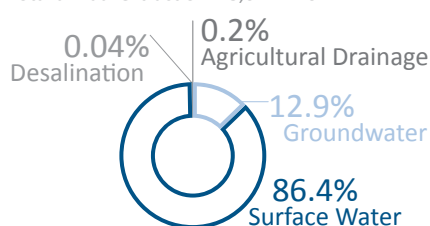
Data from 2008 [1]

Pacific
Total use: 14,484 x 10⁶ m³

0.5% 0.6%
6.8%
92.2%

Amazon
Total use: 3,334 x 10⁶ m³

2.7% 3.4%
25.0%
69.0%

Titicaca
Total use: 357 x 10⁶ m³

0.003% 2.5%
12.7%
84.8%

Data from 2013 - 2014 [19]   ■ Agricultural   ■ Municipal   ■ Industrial   ■ Mining
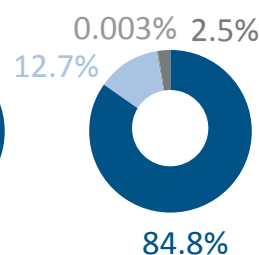
[iv] For extremely low precipitation regions such Lima, the satellite product that was used to generate the map typically overestimates precipitation [24]. Therefore, data from the hydrometeorological station was used to generate the monthly average precipitation graph for Lima.

[iv] The internal renewable water resources is the part of the water resources (surface water and groundwater) that is generated from precipitation within the country.
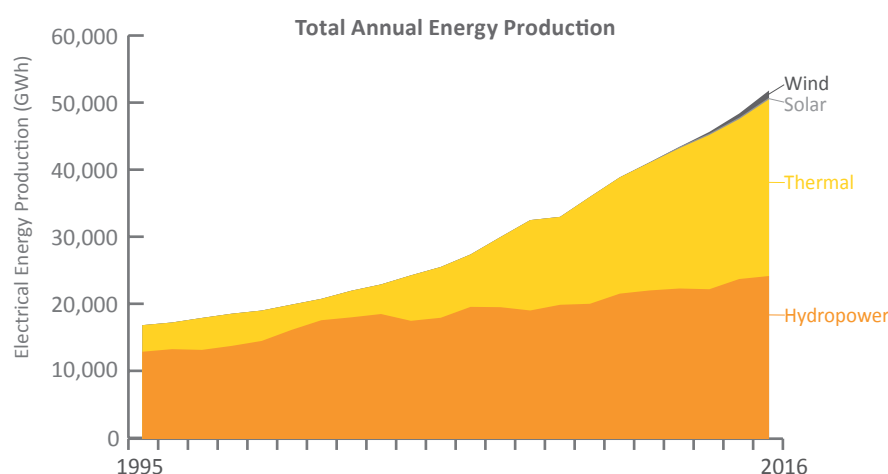
[v] The water dependency ratio is defined as percentage of total renewable water resources that originate outside of the country.

In the year 2000, 81% of energy production was from hydropower. Since then, the increase in production from thermal generation has been significantly higher than from hydropower [25]. A reason for this is due to minimal investments in hydropower in the early 2000s [26].
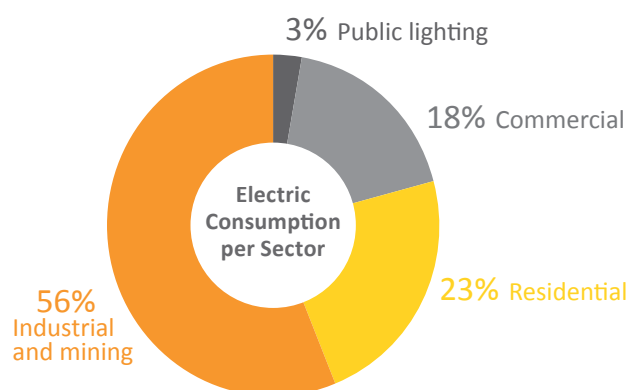
From 2003 to 2013, the increased share in energy generation from natural gas was the catalyst for the increase in thermal production, although the oil supply dropped slightly over this time [15].

1.99 metric tonnes per capita CO_2 emissions
world average: 4.97 (2014)[10]

1,308 kWh per capita Electric power consumption
world average: 3,125 (2014)[10]

45,435 GWh Total electric power consumption (2016)[25]

51,700 GWh Total electricity production[vii] (2016)[25]

38 GWh Electricity exports (2016)[25]

22 GWh Electricity imports (2016)[25]

94.9 % Percentage of population with access to electricity (2016)[10]

All values are annual

Total Annual Energy Production

Based on data from [25]

Electric Consumption per Sector

3% Public lighting
18% Commercial
23% Residential
56% Industrial and mining

Data from 2015 [27]

Of the 51,700 GWh of energy produced in 2016, 96% was for the electricity market and 4% for private use [25].

A nationwide energy security assessment concludes that the energy equity in Peru remains relatively low. The indicator was measured by rating the country's energy access, quality of supply and affordability and competitiveness [28].

[vii] The large discrepancy between production and consumption is due mainly to losses in the system and ancillary services in energy generation centres.

FOOD AND AGRICULTURAL SECTOR

There are high levels of agricultural output in the river valley in the coastal region, while agricultural activities in the highlands are predominantly of a subsistence nature [5]. The highlands areas have the highest coverage of land used for agricultural purposes [29].

2,738 million US$ Food exports (2014)[30]

3,238 million US$ Food imports (2014)[30]

243,300 km² Agricultural area[viii] (2014)[31]

25,800 km² Irrigated area (2012)[29]

7.6 % of GDP Value added by agriculture (2016)[10]

7.9 % of population Prevalence of undernourishment (2015)[10]

The total value of annual food imports and food exports have increased dramatically from 2000 to 2014 (by 360% and 740%, respectively) [30]. Agricultural production for export is concentrated in the coastal zone, despite the water scarcity in this region [15].
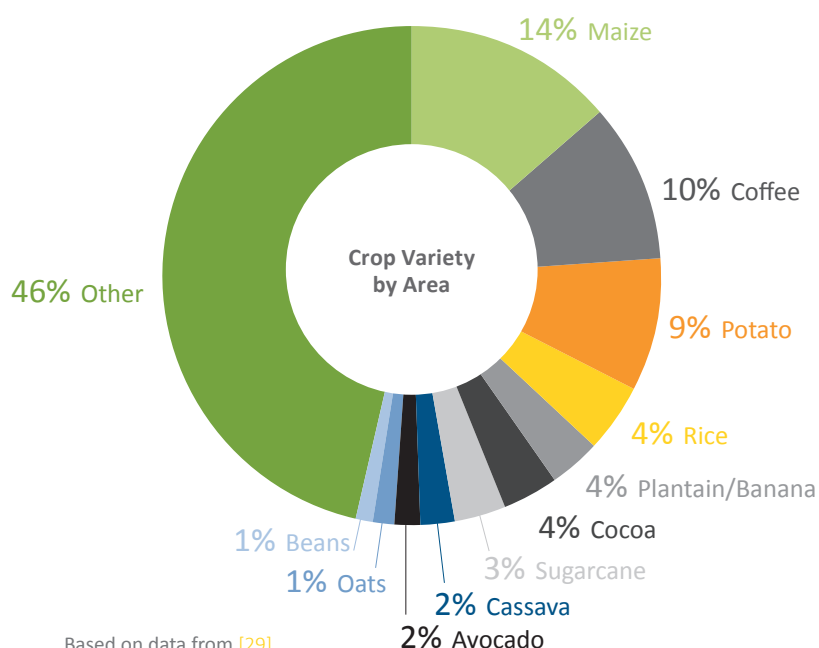
Land for farming activities
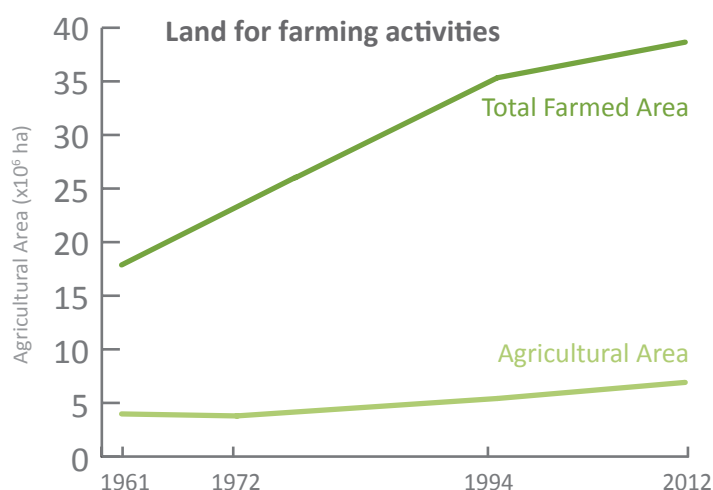
Based on data from [29]

44% of the farms use fertilisers, while 38% use chemical insecticides [29].

The two main reasons for not working on farming land are cited as a lack of water and a lack of credit [29].

The varied climatic and geographic conditions throughout the country allow the cultivation of very varied crops.

Crop Variety by Area

14% Maize
10% Coffee
9% Potato
4% Rice
4% Plantain/Banana
4% Cocoa
3% Sugarcane
2% Cassava
2% Avocado
1% Oats
1% Beans
46% Other

Based on data from [29]

Food accessibility indicators in Peru are classified as relatively low [8]. The National Food and Nutrition Security Plan 2015-2021 contains specific objectives on food availability and access, food nutrition, adaptability to climate change and the implementation of an institutional framework [32].

Climate change has the potential to cause GDP losses of up to 15% over the period 2010-2100, with these losses concentrated in the farming, high-Andean livestock and fisheries sectors [15]

[viii] The agricultural area presented by the FAO is significantly different to the 30% of the total land area (approximately 386,000 km²) presented by the INEI [29].

ENVIRONMENT

53 % Forest area (2014)[30]

21.3 % of total land area Protected land areas (2016)[10]

0.5 % of territorial waters Protected water areas (2016)[10]

At the national level, only 32% of wastewater is treated and water quality in 41 of the 98 monitored basins fail to meet environmental quality standards[ix] [15].

The majority of the forested area in Peru (92%) corresponds to humid Amazon forests. Deforestation of these Amazon forests is estimated at an average of 113,000 ha per year, which has occurred primarily in unclassified forests where there is no system of administration or protection [15].

[ix] Water quality is monitored in 98 of the country's 159 hydrographic basins.

WATER - ENERGY INTERCONNECTIONS

Water for Energy

In order to attain the National Energy Plan 2014 - 2025 goal of a 60% renewable mix, the government has authorised numerous large and small hydropower developments. In 2014, final and definitive concessions for both the Veracruz (730 MW) and Chadin 2 (600 MW) projects [33].

Water used for Electricity Generation

Based on data from [19]
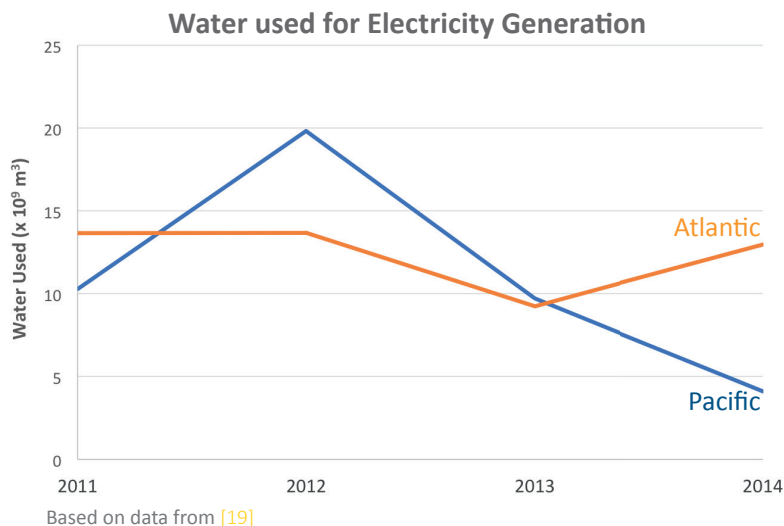
- The National Institute for Natural Resources (INRENA in Spanish) is responsible for authorising the development of studies of water resource use for power generation and for granting the license for water use for a hydropower project [26].

- The National Service of Environmental Certification for Sustainable Investments (SENACE is Spanish) oversees the reviewing and approving of Environmental impact Studies for activities that may cause significant environmental impacts [34].

One identified problem in hydropower projects is that there is no defined standard procedure for the calculation of minimum flows for ecological purposes [26].

Energy for Water

- Desalination provided a miniscule percentage (0.04%) of potable water supply in Peru in 2008, but large desalination projects are planned along the coast and construction has begun on the first large plan in Lima [1][35][36].

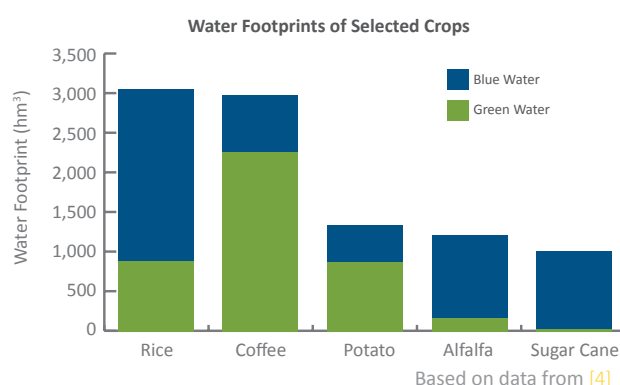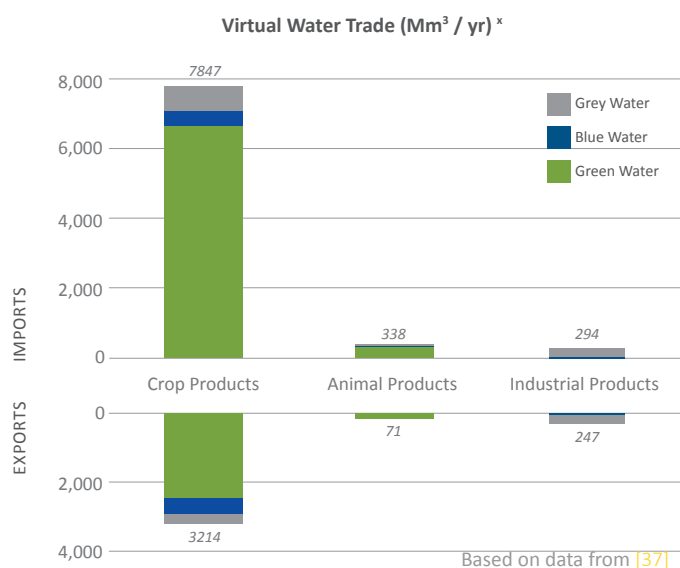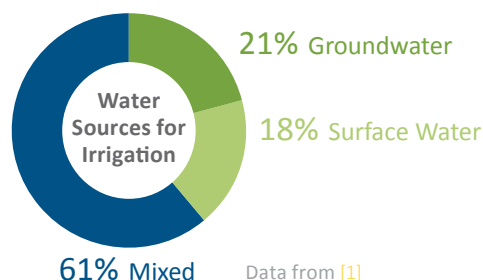- Only 32% of wastewater is processed by water treatment plants [15].

WATER - FOOD INTERCONNECTIONS

Water losses in agriculture:

The irrigated area in 2012 was 2.6 x 10^6 ha, which amounts to 36% of the total agricultural area. Of the agricultural area under irrigation, 88% uses gravity-assisted irrigation. Both drip irrigation and sprinkler irrigation are common for the remaining 12% of the irrigated area [29].

The irrigation efficiency in Peru is estimated to be 35% [1].

Water Sources for Irrigation

21% Groundwater

18% Surface Water

61% Mixed

Data from [1]

Virtual Water Trade (Mm³ / yr) ˣ

Based on data from [37]

Water Footprints of Selected Crops

Based on data from [4]

Despite the high average annual precipitation in Peru, the majority of agriculture is in the arid regions, which means that near the coast, the water footprint is predominantly comprised of blue water [4]. The five agricultural products with the highest water footprints are shown on the above graph.

Almost half of agriculture area that is unused is reported to be due to a lack of available water [29].

ˣ Virtual water refers to the amount of water needed for the production of food and other products. It can be separated into green water (water from precipitation that is stored in the root zone of the soil), blue water (water sourced from surface or groundwater resources) and grey water (the fresh water required to assimilate pollutants to meet specific water quality standards).

ENERGY - FOOD INTERCONNECTIONS

- The Law for the Promotion of the Biofuel Market sets mandatory targets for the blending of ethanol in petrol (7.8%) and biodiesel in diesel (5%). This has created a domestic market for these biofuels [38].
- Several sugar refineries use sugar cane for cogeneration [39].
- An estimate from 2011 suggests that 6.1% of the current biomass potential in the country is being exploited [40].
- The number of agricultural producers that use electric power to undertake agricultural work has increased 5.8 times over the period 1994 to 2012, yet the total number of producers using electric power is still a very low 2.1% [29].

GOVERNANCE

Policies and institutional structures

- The adoption of the General Environment Act of 2005 was able to strengthen a number of institutions [15].

- Regarding environmental policy, two significant changes have occurred in previous years: [15]
  - The Ministry for the Environment, created in 2008, was assigned the majority of the environmental responsibilities.
  - To decentralise processes, environmental responsibilities were transferred from the national government to the sub-national and local authorities.

- The 2009 Water Resources Law, the draft National Water Resources Management Strategy and the creation of the National Water Agency have built the basis for integrated water resources management in Peru [41].

- Legislative Decree No. 1058, introduced in 2008, was implemented to promote investment and developments in renewable energies [27].
  - Hydropower projects with a capacity greater than 20 MW are not considered as renewable energies under this decree [26].

Challenges faced in the governance of the WEF Nexus

- A weak institutional framework and poor governance are cited as prevalent in Peru [35].

- Institutional silos are identified as limiting the state's capacity to achieve its strategic objectives [42].

- A lack of formalised ownership of forest land is considered to contribute to the high levels of often illegal deforestation in the Amazon [15].

- Despite having a comprehensive anti-corruption legal framework, there is considered to be a poor implementation of relevant corruption laws [43].
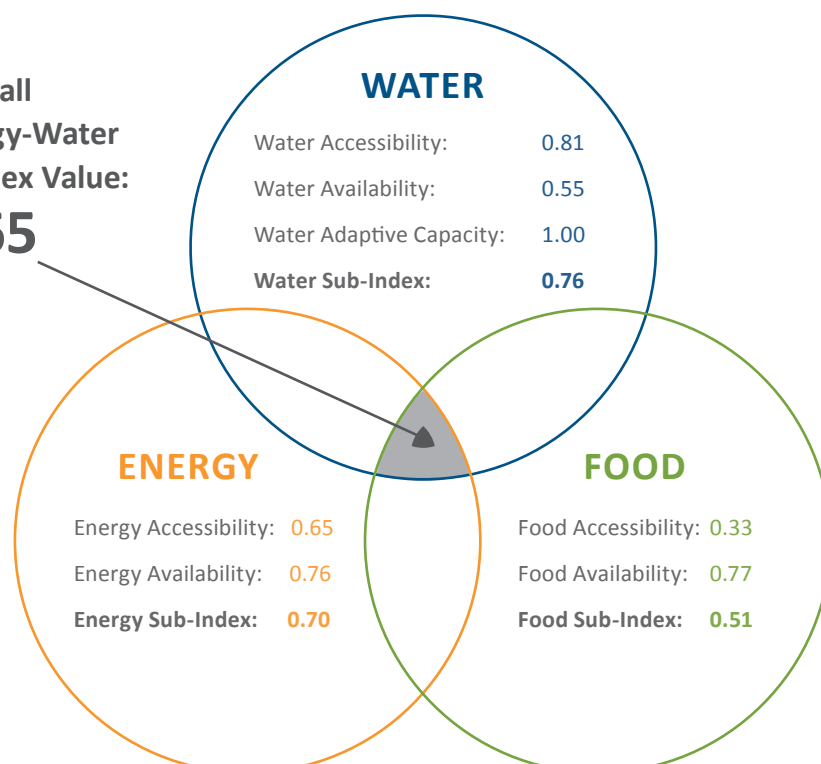
NEXUS EVALUATION

Applying the Pardee RAND Food-Energy-Water Security Index

To gain insight into the security level of each Nexus element and the overall resources security, the Pardee RAND Index for Tunisia is presented. It is calculated the following way:

- The Index is based on availability and accessibility[xi] of the resource, and in the case of the water, an analysis of the adaptive capacity is also part of the calculation.

- Normalised scores are derived by assigning a value between 0 and 1, where 0 represents the minimum value and a score of 1 represents the conditions for that sub-index which are sufficient to meet basic needs.

- All three Nexus elements are equally weighted to determine the overall security index value [8].

Overall Food-Energy-Water Security Index Value:

0.65

WATER

Water Accessibility:	0.81
Water Availability:	0.55
Water Adaptive Capacity:	1.00
Water Sub-Index:	**0.76**

ENERGY

Energy Accessibility:	0.65
Energy Availability:	0.76
Energy Sub-Index:	**0.70**

FOOD

Food Accessibility:	0.33
Food Availability:	0.77
Food Sub-Index:	**0.51**

Based on data from [36]

xi The availability considers the national scale while the accessibility considers the access to resources at the individual level.

REFERENCES

1 Food and Agriculture Organization of the United Nations (2015), 'AQUASTAT: Peru', Available from: http://www.fao.org/nr/water/aquastat/countries_regions/PER/indexesp.stm

2 DIVA-GIS (n.d.), 'Free Spatial Data', Available from: http://www.diva-gis.org/Data

3 Instituto Nacional de Estadística e Informática (n.d.), 'Población', Available from: https://www.inei.gob.pe/estadisticas/indice-tematico/population/

4 Autoridad Nacional de Agua (2015), 'Huella hídrica del Perú: sector agropecuario', Available from: http://www.ana.gob.pe/media/1256542/estudio%20huella%20h%C3%ADdrica%20nacional.pdf

5 Food and Agriculture Organization of the United Nations (n.d., a), 'Peru', Available from: http://www.fao.org/docrep/005/y4632e/y4632e0o.htm

6 Macera, D. (2018), 'Plantas desalinizadoras podrían no ser rentables por altos costos', El Comercio, Available from: https://elcomercio.pe/economia/plantas-desalinizadoras-rentables-altos-costos-noticia-497969 [Accessed on 19 June, 2018]

7 Ministerio de Energía y Minas (2014), 'Plan Energético Nacional 2014- 2025', Available from: http://www.minem.gob.pe/_detalle.php?idSector=10&idTitular=6397

8 Willis, H.H., Groves, D.G., Ringel, J.S., Mao, Z., Efron, S. & Abbott, M. (2016), 'Developing the Pardee RAND Food-Energy-Water Security Index: Toward a Global Standardized, Quantitative, and Transparent Resource Assessment', RAND Corporation, Santa Monica, Calif.

9 Vuille, M., Franquist, E., Garreaud, R., Casimiro, W.S.L. & Cáceres, B. (2015), 'Impact of the global warming hiatus on Andean temperature', Journal of Geophysical Research: Atmospheres, vol. 120, Iss. 9, pp. 3745-3757.

10 World Bank (n.d.), Peru Country Database, retrieved at https://data.worldbank.org/country/peru

11 Indexmundi (n.d.), 'GINI index (World Bank estimate) - Country Ranking', Available from: https://www.indexmundi.com/facts/indicators/SI.POV.GINI/rankings

12 United Nations Development Programme (UNDP) (2016), 'Human Development Report 2016: Human Development for Everyone', New York

13 World Bank (2018), 'Jobs Data: Peru', Available from: http://datatopics.worldbank.org/jobs/country/peru

14 García, R., Miyashiro, J., Rubio, D., Santa Cruz, P. & Marces, R. (2015), 'Desarrollo o Crecimiento Urbano en Lima: El Caso de los Distritos del Sur', Perú Hoy, Available from: http://urbano.org.pe/peru-hoy2015/

15 United Nations Economic Commission for Latin America and the Caribbean (2016), 'Environmental Performance Reviews - Peru 2016: Highlights and recommendations', Santiago, Chile

16 Instituto Nacional de Estadística e Informática (2010), 'Perú: Estimaciones y Proyecciones de Población Departamental, por Años Calendario y Edades Simples 1995-2025', Available from: http://proyectos.inei.gob.pe/web/biblioineipub/bancopub/Est/Lib1039/index.htm

17 United Nations (n.d.), 'Peru: Voluntary National Review 2017', Available from: https://sustainabledevelopment.un.org/memberstates/peru

18 Funk, C., Peterson, P., Landsfeld, M., Pedreros, D., Verdin, J., Shukla, S., Husak, G., Rowland, J., Harrison, L., Hoell, A. & Michaelsen, J. (2015), 'The climate hazards infrared precipitation with stations - a new environmental record for monitoring extremes', Scientific Data 2, 150066

19 Instituto Nacional de Estadística e Informática (2017), 'Perú: Anuario de Estadísticas Ambientals 2017', Lima.

20 Geo GPS Perú (n.d.), 'Descargar Cuencas Hidrográficas del Perú', Available from: http://www.geogpsperu.com/2014/02/descargar-cuencas-hidrograficas-del.html

21 World Meteorological Organization (n.d.), 'Lima', Available from: http://worldweather.wmo.int/en/city.html?cityId=108

22 Autoridad Nacional de Agua (2017), 'Estudio hidrogeológico del acuífero Ica: memoria final', Available from: http://repositorio.ana.gob.pe/handle/ANA/2490

23 Muñoz, I. (2016), 'Agro-exportación y sobreexplotación del acuífero de Ica en Perú', Anthropologica, vol. 34, No. 37, doi: http://dx.doi.org/10.18800/anthropologica.201602.005

24 Zambrano-Bigiarini, M., Nauditt, A., Birkel, C., Verbist, K., and Ribbe, L. (2017), 'Temporal and spatial evaluation of satellite-based rainfall estimates across the complex topographical and climatic gradients of Chile', Hydrology and Earth System Sciences, vol. 21, pp. 1295-1320.

25 Ministerio de Energía y Minas (2017), 'Anuario Estadístico de Electricidad 2016', Available from: http://www.minem.gob.pe/_estadistica.php?idSector=6&idEstadistica=11738

26 Energy Sector Management Assistance Program (2011), 'Peru Opportunities and Challenges of Small Hydropower Development', Formal Report 340/11, Washington, U.S.A.

27 Tamayo, J., Salvador, J., Vásquez, A & Vilches, C. (2016), 'La industria de la electricidad en el Perú: 25 años de aportes al crecimiento económico del país', Osinergmin, Lima, Perú.

28 World Energy Council (2017), 'World Energy Trilemma index 2017: Monitoring the Sustainability of National Energy Systems', London, United Kingdom

29 Instituto Nacional de Estadística e Informática (2013), 'Resultados Definitivos: IV Censo Nacional Agropecuario 2012', Lima, Peru

30 Food and Agriculture Organization of the United Nations (n.d., b), 'Peru', Factsheet, Available from: http://fenixservices.fao.org/faostat/static/documents/CountryProfile/pdf/syb_170.pdf

31 Food and Agriculture Organization of the United Nations (n.d., c), 'Peru', Available from: http://www.fao.org/countryprofiles/index/en/?iso3=PER

32 Ministerio de Agricultura y Riego (n.d.), 'Plan Nacional de Seguridad Alimentaria y Nutricional 2015-2021', Available from: http://www.minagri.gob.pe/portal/download/pdf/seguridad-alimentaria/plan-acional-seguridad-2015-2021.pdf

33 International Hydropower Association (2015), 'Peru', Available from: https://www.hydropower.org/country-profiles/peru, [Accessed on 19 June, 2018]

34 Servicio Nacional de Certificación Ambiental para las Inversiones Sostenibles (n.d.), 'Sobre el Senace', Available from: https://www.senace.gob.pe/nosotros/sobre-senace/

35 Matsuda, Y. (n.d.), 'Peru Institutional Governance Review', World Bank Group, Available from: http://siteresources.worldbank.org/INTANTI-CORRUPTION/Resources/peru_gov_corr_econ.pdf

36 El Comercio (2017), 'Inició construcción de primera planta desalinizadora de agua', El Comercio, Available from: https://elcomercio.pe/lima/sucesos/inicio-construccion-primera-planta-desalinizadora-agua-noticia-478924

37 Mekonnen, MM. & Hoekstra, AY. (2011), 'The green, blue and grey water footprint of crops and derived crop products', Hydrology and Earth System Sciences, vol. 15, pp. 1577-1600.

38 Pareja, PC. Sevilla, SS. & Guevara, JC. (2008), 'Estudio Sobre la Situación de los Biocombustibles en el Perú', Soluciones Prácticas, Lima.

39 Bustamente, HG. (2013), 'Matriz Energética en el Perú y Energías Renovables: VIII. Barreras para el Desarrollo de la Bioenergía', Available from: http://library.fes.de/pdf-files/bueros/peru/10183.pdf

40 International Finance Corporation (2011), 'Evaluación del Mercado Peruano para el Financiamiento de la Energía Sostenible', Available from: https://www.ifc.org/wps/wcm/connect/d2b7a280496b628ab1e1bd849537832d/SEF-Market+Assessment+Peru-Resumen+Ejecutivo-Final.pdf?MOD=AJPERES

41 World Bank (2016), 'Building the Basis for Integrated Water Resources Management in Peru', Available from: http://www.worldbank.org/en/results/2016/09/22/building-the-basis-for-integrated-water-resources-management-in-peru

42 OECD (2016), 'Public Governance Reform - Peru: Highlights 2016', Available from: https://www.oecd.org/gov/public-governance-review-peru-highlights-en.pdf

43 GAN (n.d.), 'Peru Corruption Report', Available from: https://www.business-anti-corruption.com/country-profiles/peru/