Peru

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.

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.
Population growth

<table>
<thead>
<tr>
<th>Year</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965</td>
<td>11,608,000</td>
</tr>
<tr>
<td>1975</td>
<td>15,230,000</td>
</tr>
<tr>
<td>1985</td>
<td>19,545,000</td>
</tr>
<tr>
<td>1995</td>
<td>24,039,000</td>
</tr>
<tr>
<td>2005</td>
<td>27,610,000</td>
</tr>
<tr>
<td>2015</td>
<td>31,377,000</td>
</tr>
<tr>
<td>2025</td>
<td>34,412,000</td>
</tr>
</tbody>
</table>

Based on data from [10] and [16]

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

1 The gross national income (GNI) is the sum of a nation’s gross domestic product and the net income it receives from overseas.
2 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.
3 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.
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.

**<10 to 5,110 mm**
Annual precipitation
(average of 1,520 mm) [18]

1,641,000 x 10^6 m^3/yr
Internal renewable water resources [1]

61,884 m^3/yr
Internal renewable water resources per person [1]

19,100 x 10^6 m^3/yr
Total water consumption [2014] [19]

13% Water dependency ratio [1]

86.7% Population with access to improved drinking water sources [2015][21]

76.2% Population with access to improved sanitation facilities [2015][21]

5,770 x 10^6 m^3
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 Titiaca. 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**

<table>
<thead>
<tr>
<th>Region</th>
<th>Total use: 14,484 x 10^6 m^3</th>
<th>Agricultural</th>
<th>Municipal</th>
<th>Industrial</th>
<th>Mining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific</td>
<td>6.8% 0.5% 92.2%</td>
<td>25.0%</td>
<td>12.7%</td>
<td>0.003%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Amazon</td>
<td>2.7% 3.4% 69.0%</td>
<td>3.4%</td>
<td>12.7%</td>
<td>2.5%</td>
<td>0.003%</td>
</tr>
<tr>
<td>Titiaca</td>
<td>0.003% 2.5% 84.8%</td>
<td>2.5%</td>
<td>12.7%</td>
<td>0.003%</td>
<td>2.5%</td>
</tr>
</tbody>
</table>

For extremely low precipitation regions such as 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.

The internal renewable water resources is the part of the water resources (surface water and groundwater) that is generated from precipitation within the country.

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].

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].

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1.99 metric tonnes per capita CO₂ 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 (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

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

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.

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\textsuperscript{ix} \cite{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 \cite{15}.

\textsuperscript{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 \cite{33}.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{water_energy_interconnections.png}
\caption{Water used for Electricity Generation}
\end{figure}

One identified problem in hydropower projects is that there is no defined standard procedure for the calculation of minimum flows for ecological purposes \cite{26}.

Energy for Water

\begin{itemize}
\item 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 \cite{1][35][36].
\item Only 32% of wastewater is processed by water treatment plants \cite{15}.
\end{itemize}
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].

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).

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].

<table>
<thead>
<tr>
<th>Water Sources for Irrigation</th>
<th>21% Groundwater</th>
<th>18% Surface Water</th>
<th>61% Mixed</th>
</tr>
</thead>
</table>

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 accessibilityδ 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]δ The availability considers the national scale while the accessibility considers the access to resources at the individual level.
REFERENCES
