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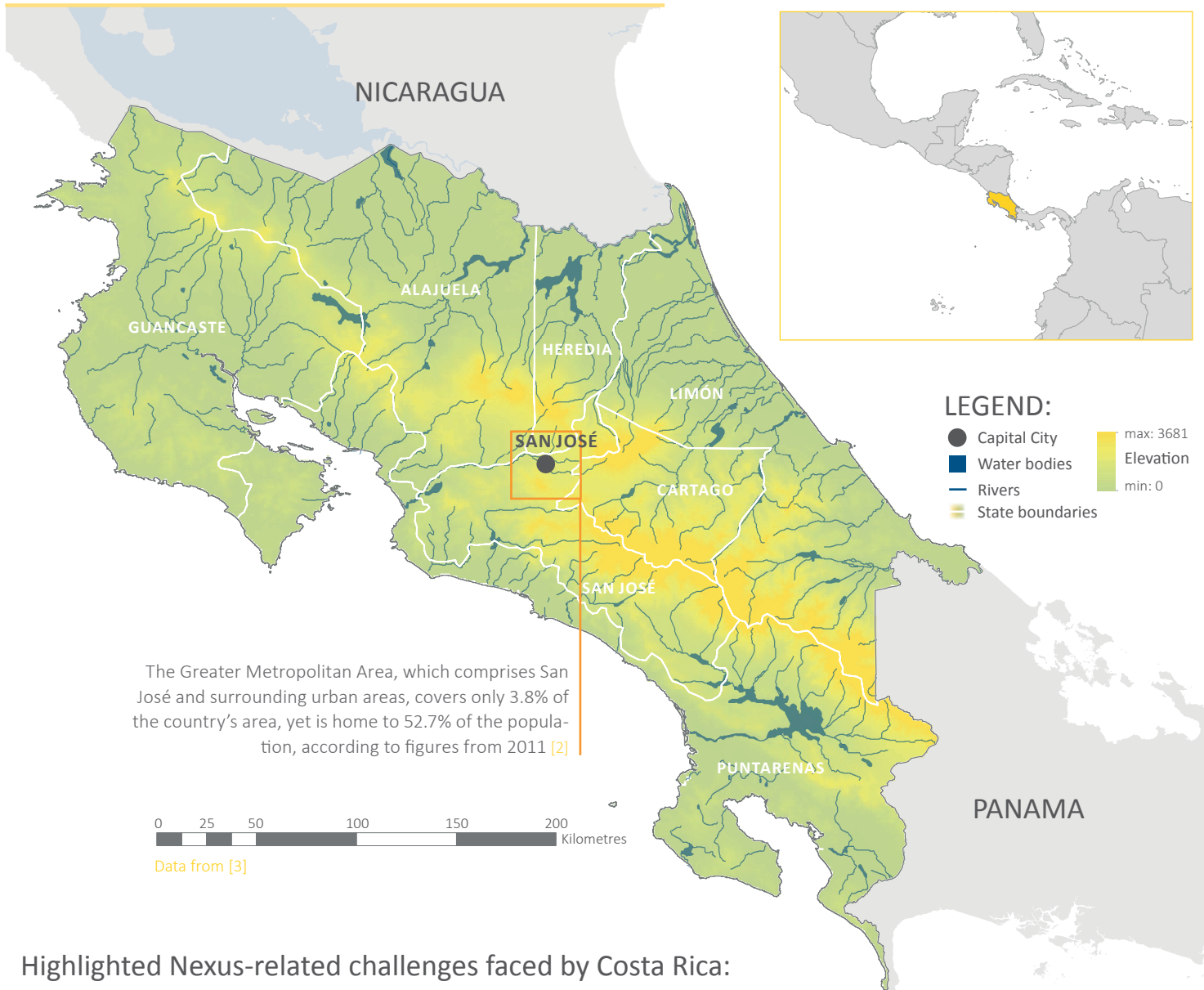
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Costa Rica

The Water-Energy-Food Security Nexus Country Profile

Costa Rica is located in Central America and shares borders with Nicaragua and Panama. It is located in the tropics, only 10 degrees north of the equator, has a mountain range extending through the country, and its climate is tropical and subtropical. [1]



Highlighted Nexus-related challenges faced by Costa Rica:

- Long-term climate projections indicate that hydrometeorological extremes, in particular droughts, are expected to increase in frequency in Costa Rica, creating a challenge for various natural resources
- Costa Rica has a large installed hydropower capacity and reliance, and planning hydropower operations while catering to other water needs poses a distinct challenge
- Food production is subject to hydrological drought, and Costa Rica has a large reliance on imported grains
- Socioeconomic development, especially in the over-exploited Reventazón River Basin, increases pressure on resources demand
- No laws specifically address the Nexus interconnections, making governance of Nexus issues through existing laws a challenging process

GENERAL INFORMATION

51,100 km² Size [4]

4,860,000 Population (2016)[4]

1.0% Population growth
annual (2016)[4]

77.7% Urban Population (2016)[4]

57.4 billion US\$ Total GDP (2016)[4]

10,840 US\$ GNI per capitaⁱ (2016)
World average: 10,308 [4]

1.6% Poverty headcount ratio at \$1.90 a day (2015)[4]

0.482 Gini coefficientⁱⁱ (2015)[4]
Ranked the 19th most unequal of 158 countries rated [5]

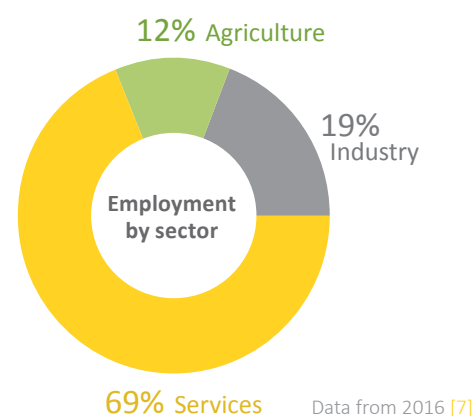
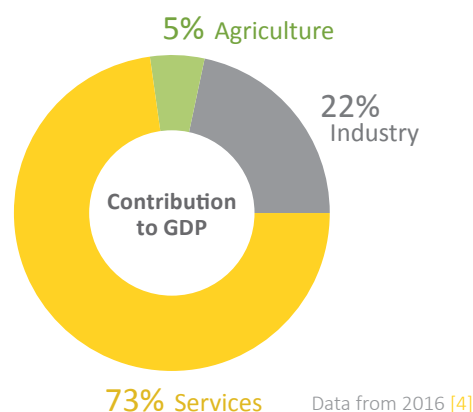
0.776 HDIⁱⁱⁱ (2015)
Ranked 66th of 188 countries rated [6]

96.4% School Enrolment, Primary (2015)[4]

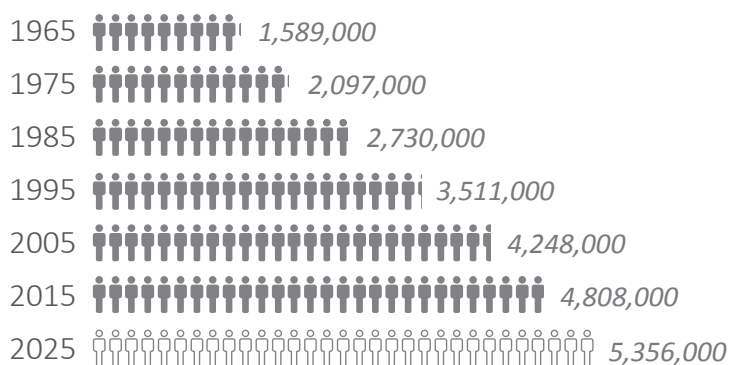
87.4% Literacy rate (over 15) (2011)[4]

79.6 years Life expectancy (2015)[4]

7.7 per 1000 births Infant mortality rate (2016)[4]



Population growth



World Bank data indicates that in 1990, 26% of employment was in the agricultural sector, and this number has fallen to just 12% in 2016. Employment in industry has also reduced in this time, with these jobs replaced by a large increase in the services industry. [7]

Implementation of the Sustainable Development Goals (SDGs): [9]

- In 2016, a national pact for the SDGs was signed
- A governance structure was established in order to attain these goals
- Programmes and projects specific to the goals have been set out. For example, training activities relating to food security, employment and rural development as part of the “zero hunger” goal
- However, the country faces difficulties in terms of establishing long-term strategies to attain these goals

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

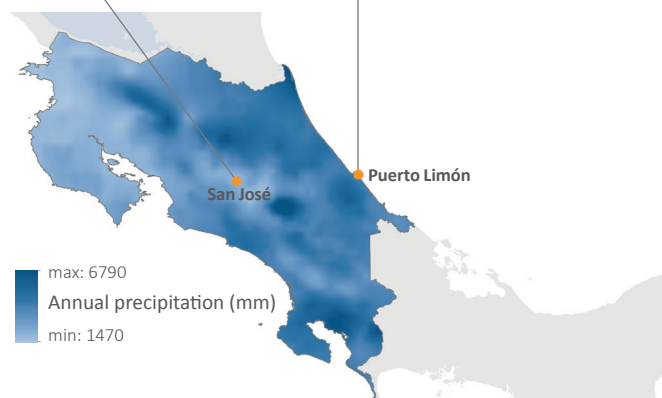
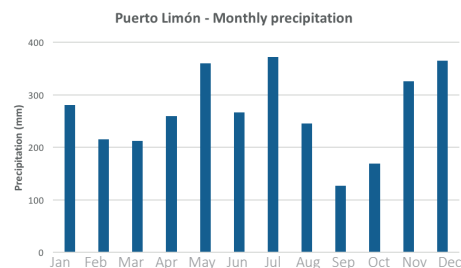
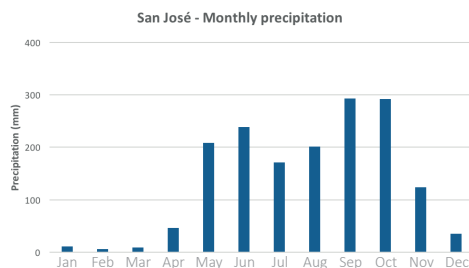
ⁱⁱ The Gini coefficient is used as a gauge of economic inequality, measuring income distribution among a population. The coefficient ranges from 0 to 1, with 0 representing perfect equality and 1 representing perfect inequality.

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

Owing to its tropical location and the mountain range that runs along the country, two regions can be identified with distinct precipitation trends. The Pacific side of the mountain range has strongly defined dry and wet seasons, with the wet season occurring from May to October. The Caribbean side has less-defined wet and dry seasons. [10]



Data from: [11]

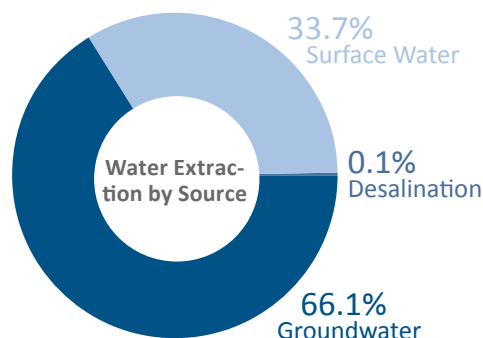
- 1,470 - 6,790 mm** Annual precipitation (average of 2,980 mm) [11]
- 112,980 x 10⁶ m³/yr** Internal renewable water resources^{iv} [10]
- 23,190 m³/yr** Internal renewable water resources per person (2013) [10]
- 0%** Water dependency ratio^v [10]
- 97.8%** Population with access to improved drinking water sources (2015)[4]
- 94.5%** Population with access to improved sanitation facilities (2015)[4]
- 1,997 x 10⁶ m³** Total capacity of dams/reservoirs (2011)[10]

The El Niño and La Niña phenomena affect the rainfall patterns in Costa Rica: on the Pacific side, El Niño typically reduces rainfall while La Niña sometimes increases precipitation; on the Caribbean side, El Niño typically increases rainfall while La Niña can reduce rainfall [12].

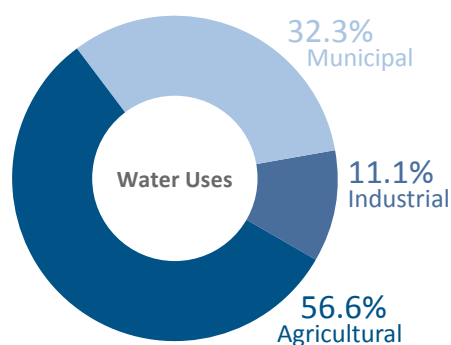
Both flooding and droughts occur in the country. For example, the recent El Niño event brought severe droughts to the north-west of the country, yet there were also areas on the Caribbean coast affected by flooding over this time [13].

Projected increasing temperatures, coupled with lower precipitation in the drier months mean that the risks of drought, especially on the Pacific coast, are likely to exacerbate in the future [14].

Desalination: Until recently, Costa Rica has not relied on desalination for water supply [10]. However, in the drought-prone province of Guanacaste (north-west of the country), one plant was recently built (2016), and plans are in place to build several more [15].



Total annual extraction: 2,350 x 10⁶ m³
Data from 2013 [10]



Data from 2013 [10]

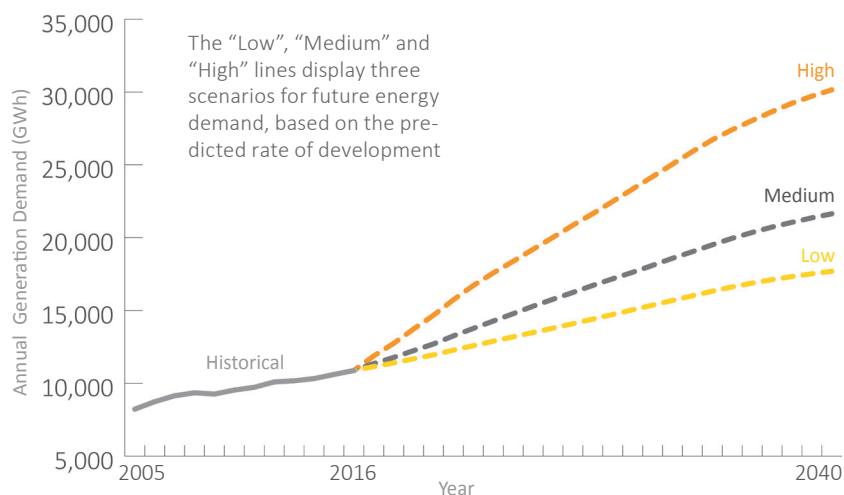
^{iv} The internal renewable water resources is the part of the water resources (surface water and groundwater) that is generated from precipitation within the country.

^v The water dependency ratio is defined as percentage of total renewable water resources that originate outside of the country.



ENERGY SECTOR

Costa Rica generates the majority of its energy from renewable resources (predominantly hydropower). In 2015, the country managed 75 consecutive days without the use of hydrocarbons [16], and in 2016, 98.2% of energy produced was renewable [17].



Based on data from [18]

The majority of the energy production (68.3% in 2016) is generated by the Costa Rican Institute of Electricity [17].

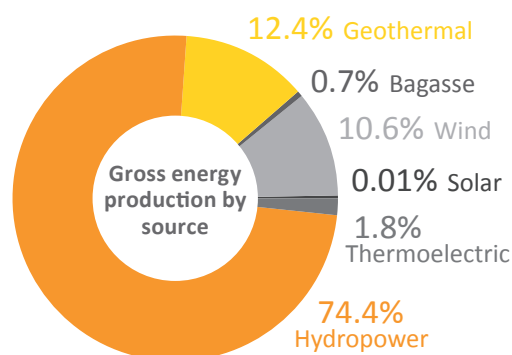
Costa Rica relies on energy imports during the dry months March, April and May, when hydropower generation is down [17].

The high reliance on hydropower is identified as a reason that energy security could reduce in the future, because of the long dry periods that are likely to occur [19].

1.63 tonnes per capita	CO ₂ emissions world average: 4.97 (2014)[4]
1,958 kWh per capita	Electric power consumption world average: 3,125 (2014)[4]
10,932 GWh	Total electric power consumption (2016)[17]
10,782 GWh	Total electricity production (2016)[17]
181 GWh	Electricity exports (2016)[17]
313 GWh	Electricity imports (2016)[17]
99.4 %	Percentage of population with access to electricity (2014)[4]

All values are annual

Contrary to the data from 2016, the electricity exports were higher than the imports in 2015. This suggests that there is no constant dependence on electricity produced externally.



(2016 total production: 10,782 GWh)
Based on data from [17]



FOOD AND AGRICULTURAL SECTOR

37% of the surface area in the country is used for agricultural purposes. [10]
82% of the farms use fertilisers, while 90% of the farms use pesticides. [20]

3,080 million US\$ Food exports (2014)[21]

1,306 million US\$ Food imports (2014)[21]

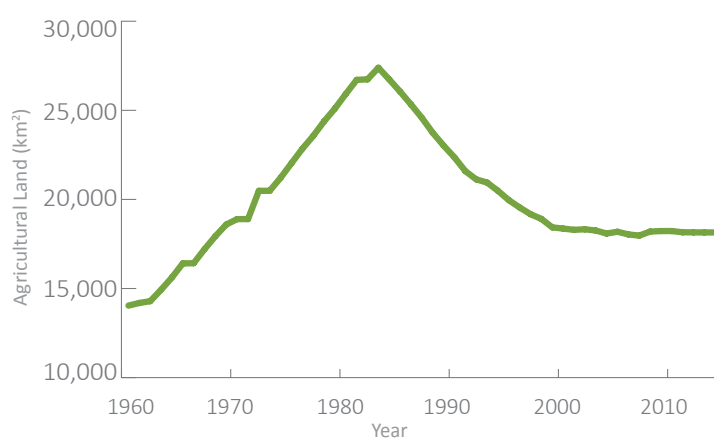
18,111 km² Agricultural area (2014)[22]

1,015 km² Irrigated area (2013)[10]

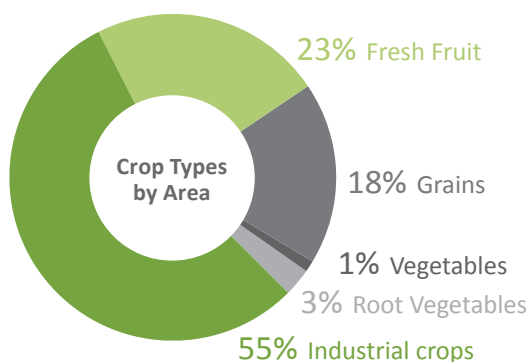
5.5 % of GDP Value added by agriculture (2016)[4]

5.6% of population Prevalence of undernourishment (2015)[4]

Between 1960 and 1986, Costa Rica underwent extremely high levels of deforestation, which was then reversed after 1986, with sustained efforts to recover forest areas. This trend, coupled with structural production changes (eg. land reallocated to permanent crops) explains the reduction in agricultural land area from its peak in the mid 1980s. [23]



Based on data from [4]



Data from 2010 [24]

Data from 2008 indicate that industrial crops account for more than half of the crop area. The main industrial crops are coffee (22.0%), sugar cane (12.5%), African palm (11.6%) and oranges (5.6%). Other major crops by area are from fresh fruits: banana (9.9%) and pineapple (7.5%) and from grains: rice (13.9%). [24]

Basin grains: The highest food security risk is for grains, and the risk is highest in El Niño years, in the Pacific regions of the country. In 2008, due to high food prices and a reliance on imports for basic grains, the National Food Plan was implemented in Costa Rica, which aimed to alleviate the effects of the international food crisis.

On average, 61% of staple grains consumed in Costa Rica are obtained from food imports, and these imports are from countries highly vulnerable to hydrometeorological events, with water availability playing a key role. [25]

ENVIRONMENT

27,258 km² Forest area (2014)[22]

27.4% of total land area Protected land areas (2014)[4]

15.8% of total water area Protected water areas (2014)[4]

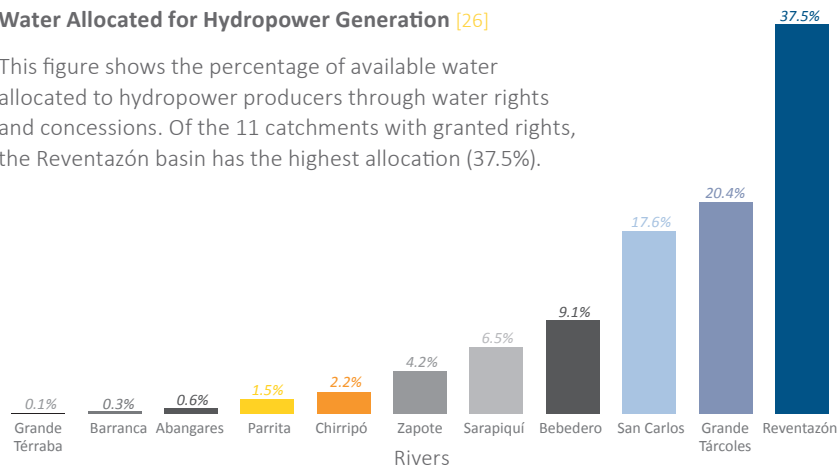
A lack of wastewater treatment has affected the water quality in the country. A severe example of this is in the lower River Puríes sub-basin, where the level of contamination has made it unsafe to use the river for water supply and agricultural purposes [26].



WATER - ENERGY INTERCONNECTIONS

Water Allocated for Hydropower Generation [26]

This figure shows the percentage of available water allocated to hydropower producers through water rights and concessions. Of the 11 catchments with granted rights, the Reventazón basin has the highest allocation (37.5%).



Based on data from [26]

The three basins with the highest percentage of hydropower allocation are shown on this figure. It is important to note that the middle of the country (i.e. the Grande Tárcoles and Reventazón basins) are highly populated and are home to extensive agricultural activities.

The Reventazón hydropower facility (305.5 MW), the largest in the country, came online in 2016. The proposed El Diquís hydroelectric project (631 MW) would be the largest in Central America [27]. These are both shown on the map.

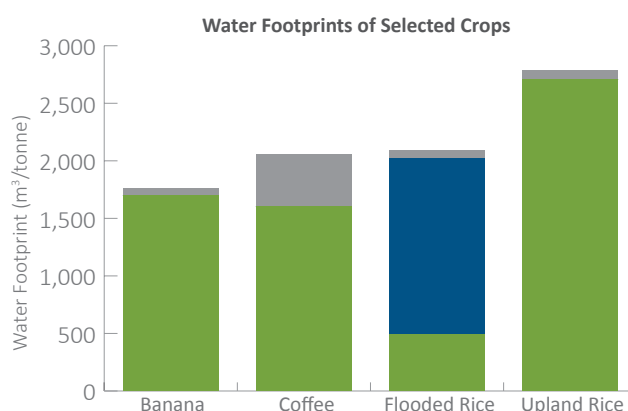
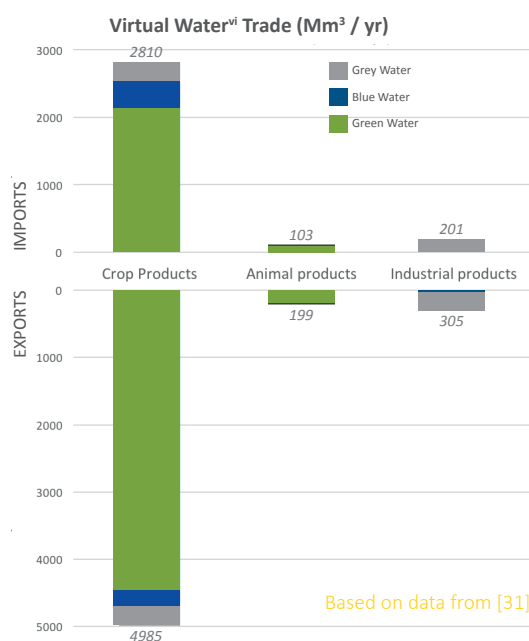


- Water laws in Costa Rica do not specify environmental flow conditions, hence an administrative rule exists which impose a 10% reserve. However, this isn't always enough to maintain a functioning ecosystem, or this rule is not followed [26]. The Reventazón Hydroelectric Project is part of a cascade of projects on the Reventazón River, and is designed to maintain a downstream flow of 40 m³/s. A turbine (13.3 MW) is installed to utilise the environmental flow release. [28]
- The emptying of dams and reservoirs for cleaning can also affect water quality. One such example is the Cachí Reservoir, which contributes almost 500,000 tonnes of suspended sediments annually [26].



WATER - FOOD INTERCONNECTIONS

- Values from 2013 indicate that 94% of the irrigated area (954 km²) is irrigated using surface water, while the remaining 6% (61 km²) is irrigated using extracted groundwater [10]
- High levels of pesticide use in agriculture has severely affected both surface water and groundwater quality in numerous basins in the country [29]
- Food production is highly susceptible to hydrometeorological events: as a result of both the drought on the Pacific coast and flooding on the Caribbean coast from the 2014-2015 El Niño event, losses of USD 6.9 million and USD 6.7 million were estimated in the agriculture and livestock sectors, respectively [25]
- Despite a number of irrigation infrastructure projects being implemented by SENARA (the responsible national agency), demands for irrigation have still often not been met [26].



Water footprints of coffee, rice and banana plantations in Costa Rica (which account for 44% of the agricultural area) are shown above. A high quantity of the coffee and bananas produced are exported. [30]

^{vi} 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

- Biomass was used to generate 74.5 GWh of energy in 2016 (0.69% of national generation). Biomass use in Costa Rica does not compete with food production; food residues are used instead of crops grown specifically for biofuels. [32]
- To use water more efficiently, there is a push from authorities in the agricultural sector to modernise irrigation systems [26]. As of 2013, only 15% of the total irrigated area would be classified as “modernised irrigation” [10]. This process of modernising irrigation systems increases the energy demands for irrigation.
- There is a lack of available water for irrigation in the upper part of the Reventazón River Basin. Therefore, options such as a water transfer from other basins have been investigated, which would significantly increase energy requirements due to the pumping that would be needed. [26]

GOVERNANCE

From the 1940s to today, numerous pieces of legislation were introduced which are related to elements of the Nexus, but they did not directly address Nexus interconnections. Some of these are [26]:

- Law No. 276 (1942) - Defined water as a public good and gave the MINAE the authority to grant water rights
- Law No. 1657 (1953) - Established a reserve zone for hydropower generation in the Reventazón river basin
- Law No. 8023 (2000) - Created a commission for the planning, regulation and control of activities in the Reventazón river basin

Many of the laws governing the Nexus were outdated, and the problems of duplicate functions or regulatory gaps existed. To address these deficiencies, in 2016, The Law for Integrated Water Resources management in Costa Rica was presented to the legislative assembly. This law (Expediente N° 20.212) underpins the need to regulate management and sustainable use of water in the country, and therefore is essential in the application of a Nexus approach [26]. Key aspects of this law are:

- The multiple use of water is considered as essential
- Minimum environmental flows to satisfy ecosystem demands need to be addressed
- Definition of an order of priorities for water uses
- The state has the power to restrict some of the granted water rights in times of water deficit

Success story of Nexus cooperation: after accelerated erosion rates from intensive agriculture and livestock raising led to increased sedimentation in hydropower reservoirs, the government established the “National Fund for Forest Financing.” Hydropower companies contributed to the fund which was used for tree planting and other conservation efforts that reduced soil erosion. This was an effective strategy in minimising food-energy Nexus trade-offs. [33]

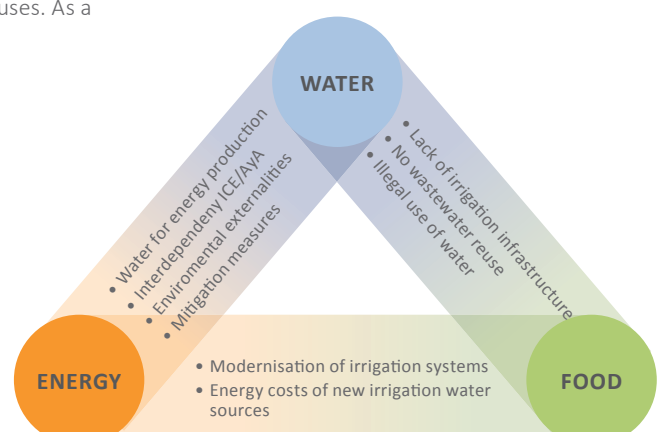
REVENTAZÓN RIVER BASIN - CASE STUDY

The Reventazón River Basin covers an area of $2.8 \times 10^6 \text{ km}^2$, making it the third largest basin in Costa Rica. Because it is intensively used for hydropower generation, agriculture and drinking water supply, it is an important case study when analysing Nexus interconnections in Costa Rica. It is also the only river basin in the country with a legally regulated administrator.

- Population of almost 500,000 [26]
- Provides 25% of the drinking water of the Costa Rican Greater Metropolitan Area, which is located outside the basin [34]
- In terms of the national production: [26]
 - 38% of hydropower generation
 - 50% of cement production
 - 85% of vegetable production
 - 30% of milk and meat production
- Installed hydropower of 305 MW [35]
- Law No. 1657 (from 1953) defined the Reventazón River Basin as a natural reserve for hydropower, which limited the use of the water resource for other uses. As a result, the Costa Rican Institute of Electricity have refused many other applications for water rights, especially to the agricultural sector. [26]

The equilibrium of this basin has been threatened by anthropogenic degradation processes and the inadequate use of the natural resources, mainly soil and water.

13% of the soil in the basin is considered to be overused, which produces serious erosion problems. More than 94 tonnes of solid waste are produced within the basin, of which 26% is not collected. Furthermore, approximately 772 tons of sediments per year are deposited at the bottom of the dams of hydropower plants. The inexistence of urban waste water treatment plants, the over-application of chemical fertilisers and pesticides, and the bad disposal of solid residues in farms and cities have made the Reventazón River the second most contaminated river of Costa Rica [26].



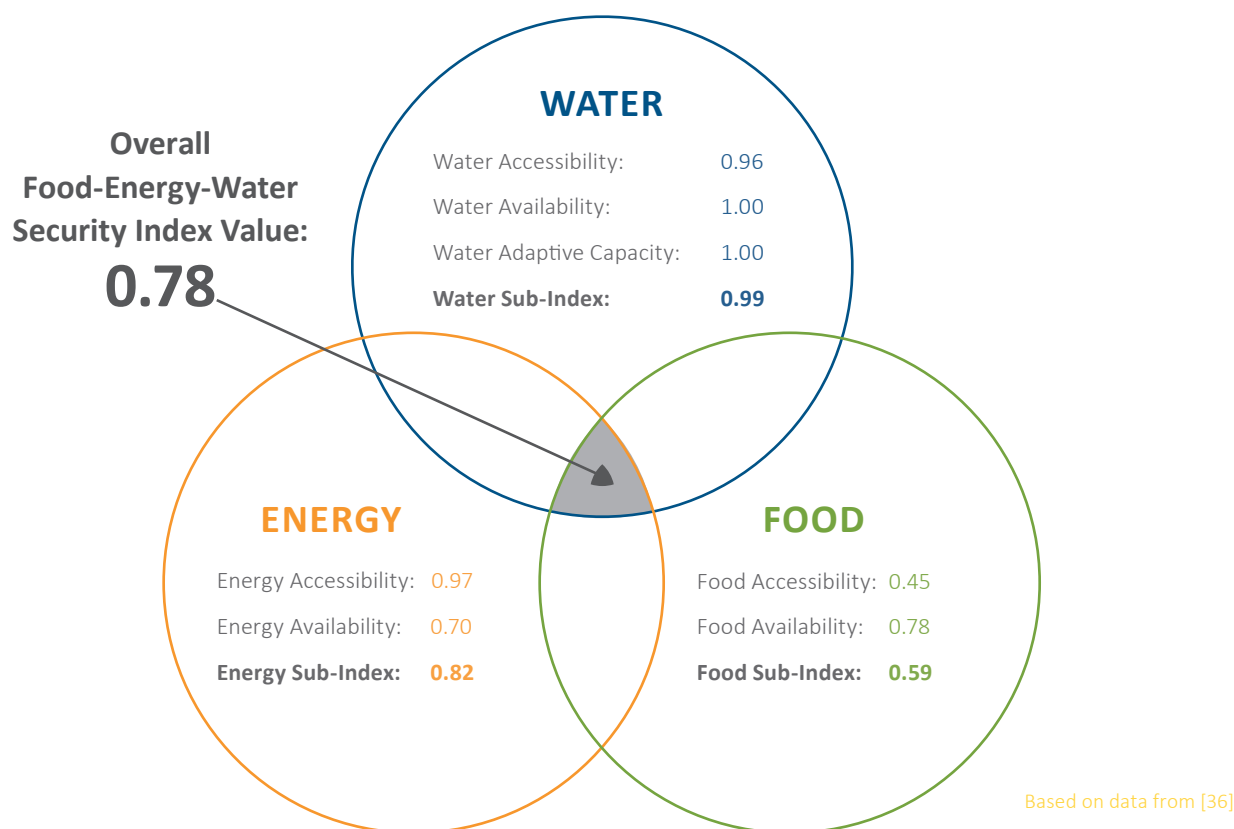
Summary of Nexus interconnections in the Reventazón basin

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 Costa Rica is presented. It is calculated the following way:

- The Index is based on availability and accessibility 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 [36]



^{vii} The availability considers the national scale while the accessibility considers the access to resources at the individual level.

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