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Water-Energy-Food Sustainable Development Goals in Morocco

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Definitions

Water, energy, and food security challenges are complex and tightly interconnected (Hoff 2011; Mohtar and Daher 2012; FAO 2014a; IRENA 2015). Food production demands water; water extraction, treatment, and redistribution demand energy; and energy production requires water. With growing pressures on these interconnected resource systems due to climate change and population growth, it is critical that we understand and quantify those interlinkages to minimize the competition that might arise as different sectors plan for their future development. The water-energy-food nexus is an approach that offers an equidistant platform for multi-sectoral evidence-based dialogue about trade-offs associated with decisions made across the different sectors (Mohtar and Daher 2016). As countries work toward achieving the Sustainable Development Goals, the WEF Nexus approach could play a role in ensuring that decisions made across sectors do not advance goals at the expense of others (Stephan et al. 2018).

Introduction

In September 2015, world leaders committed to work toward achieving 17 Sustainable Development Goals (SDGs) as part of their 2030 sustainable development agenda. Each Goal includes a list of quantifiable targets to achieve during the 15-year term. As each nation works toward achieving this agenda, there are risks of potential competition between specific targets, which could cause unintended consequences and additional. These issues become particularly complex when focusing on the three highly interconnected Water, Energy, and Food Goals (2, 6, and 7): the strategy for one directly affects the other two. While it is important that we work toward achieving all 17 Goals, it is equally important that we understand the level of their interconnectedness and the potential competition between them.

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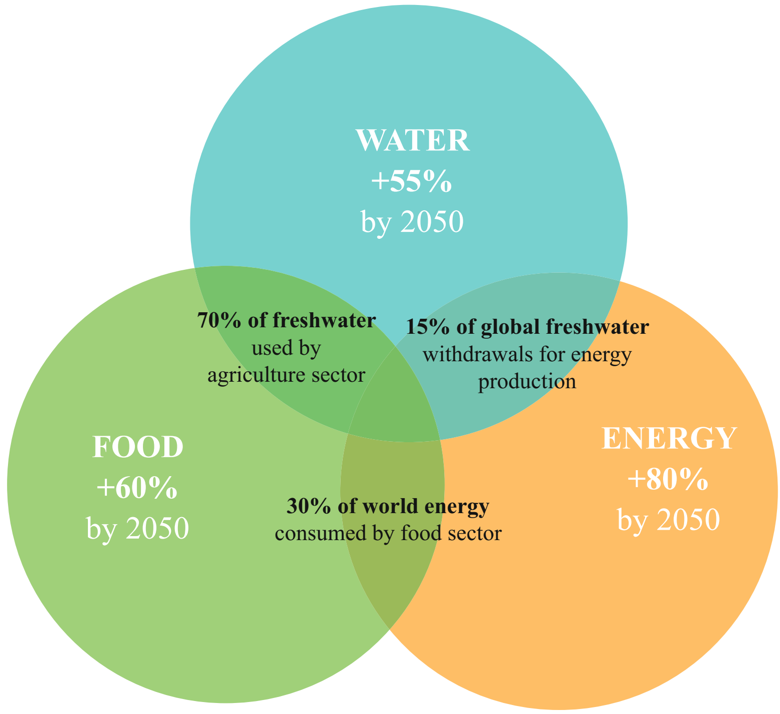
The challenges facing water, food, and energy resource systems are tightly interconnected (Fig. 1). One of the main gaps identified in this growing body of literature is the need for holistic, integrative evaluation of different resource strategies (Biggs et al. 2015). Quantitative assessment tools can play a major role in providing insights regarding the trade-offs associated with possible future pathways by informing policy and investor decisions (ICSU 2017). Tools that cover various aspects of the interconnected resource systems exist in the literature and can be used and customized to address specific resource hotspots (Albrecht et al. 2018; Stephan et al. 2018; Beisheim 2013; Bizikova et al. 2014; Boelee et al. 2014; Brandi et al. 2013; ESCWA 2015; FAO 2014a, 2014b; Hoff 2011).

Quantitative tools play an important role in highlighting the trade-offs associated with different pathways toward achieving the SDGs. This chapter explores the role of such tools within the context of Morocco as a case study. In the face of increasing stresses – rapidly growing populations and cities, climate change, and booming industrial sector, particularly its phosphate industry – Morocco recently announced several national plans for better managing its water, energy, and food systems. This entry starts by demonstrating the interconnections between SDGs 2, 6, 7 and the role of quantitative tools in assessing the impact of the water targets upon the food and energy targets in Morocco. This is followed by exploring examples of trade-offs for implementing different levels of the proposed water, energy, and food national plans, as well as possible social, policy, technical interventions that carry the potential for reducing existing competition and ensuring more sustainable resource allocation in the three national plans at multiple scales.

Why Morocco?

Morocco is a lower middle-income country on the North African coast of the Atlantic Ocean and the Mediterranean Sea (Berkat and Tazi 2006). Its major economic sectors are industry (mainly phosphate production), services (tourism), and agriculture (CIA 2015). Although agriculture accounts for only 13.8% of the GDP, it employs 40% of the working population (The Columbia Electronic Encyclopedia 2012). As part of its national strategy for agriculture, the Green Morocco Plan for 2010–2020 (Agricultural Development Agency 2008) includes plans to double GDP from agriculture and add 15 million jobs (Al monitor 2014). The plan focuses on increasing olive, citrus, fruit, and vegetable production, while investing in technologies that increase the yields for cereal production and thereby releases agricultural land for potential production of higher value crops. Morocco is a highly water-stressed country with decreasing ground and surface water supplies (FAO Aquastat 2016). Even though agriculture is Morocco's predominant water user, estimates are that only about 15% of Morocco's arable farmland is irrigated, with the remainder dependent on rainfall (USAID 2016). Morocco's high susceptibility to climate change makes it particularly vulnerable in terms of food and water security (El Badraoui and Berdai 2011), and makes it essential that Morocco find other solutions to diversify its water portfolio. Such solutions include investment in alternatives such as desalination, which will also impact the energy sector. Morocco depends primarily on imports for energy: by 2030, the Moroccan Water Strategy aims to increase the quantity of desalinated water to 400 km^3/year and of treated wastewater to 300 km^3/year (Abdelhamid 2013; African Development Bank 2009; FAO Aquastat 2016).

In 2013, Morocco imported 91% of its energy (IEA 2014). In 2010, approximately 30% of energy came from renewable sources; the remaining 70% from fossil fuels (Norton Rose Fulbright 2012). Morocco's government estimates future demand for primary energy will triple or quadruple in the next 20 years (M. Anwar and Ben Salem 2011), presenting a challenge to the government, whose current low local energy production fails to meet demand. Through the Morocco Energy Strategy 2030, the country plans a significant increase in dependence on renewable energy, particularly solar and wind. Indeed, Morocco plans, by 2020, a $13 billion



Water-Energy-Food Sustainable Development Goals in Morocco, Fig. 1 Interconnected water, energy, and food security challenges. (Source: Adapted from IRENA 2015)

expansion of wind, solar, and hydroelectric power generation capacity (by 2GW each), through which it will supply 42% of its electricity (Moroccan Energy Ministry MEMEE 2015). According to the UN Population Division (2015), projections for population growth indicate that even the most conservative estimates will lead to growth in population by 2050. The moderate scenario shows an increase of 1.2%, while the high growth scenario exceeds 3%. With over 75% of global phosphate reserves, the heart of agriculture and soil enhancement, Morocco is positioned to play a leading role in contributing to global food security through growth in this industry (OCP 2016). Morocco's 2012 phosphate production represented more than a quarter of the global market share. The country recently launched an ambitious industrial development program of 1.30 billion dollars, which aims to double current mining capacity and triple chemical capacity by 2020. Different stages of phosphate mining and chemical processing require considerable amounts of water, energy, land, and resource inputs. Water recycling and reverse osmosis desalination currently contribute to securing the needed water for these processes, thereby releasing some of the pressure on scarce freshwater resources. Nevertheless, different water sources come with different energy tags that must be accounted for, especially when around 90% of the energy it consumes is imported.

Morocco's national plans for the coming decade map various targets within the water, energy, and food SDGs. While plans for all three are to achieve important goals, without sufficient coordination consistent with their interdependence, these strategies could lead to potential competition between them. Highlighting possible trade-offs in executing various national plans allows for informed dialogue that will help avoid unintended consequences in implementation of the plans. This need to identify areas of potential overlap and competition is echoed in the summary of the Moroccan voluntary national review of 2016, which explicitly highlights the need to adopt a sectoral approach that "promotes integration and coherence between sectoral development policies" (United Nations 2016). The following section presents a tool that provides explicit quantification of the interconnections between the three strategies. The subsequent sections demonstrate the tool.

Indicators, Targets, Goals, National Strategies

This entry builds on a water-energy-food framework, developed by Daher and Mohtar (2015) that identifies critical interlinkages across the three resource systems. The framework is customized to the Moroccan context and includes a link to the impact on achieving the Sustainable Development Goals.

There is ongoing debate over the choice of indicators to measure progress toward specific targets and regarding the degree to which these indicators need to be localized. In order to demonstrate for this study, three targets within goals 2, 5, and 7 were chosen for the analysis (Fig. 2):

i. Due to the complexity and unavailability of data, covering the interactions between the 15 distinct targets under SDGs 2, 5, and 7 with the list of indicators is challenging.
ii. Each target has an identified plan toward which the State of Morocco is working in the coming 15 years. Thus, data for indicators (current and projected status) associated with the plans is in the literature.
iii. Lessons learned from experimenting with the three targets and demonstrating their interaction will facilitate implementing the same protocols, providing a more complex picture that covers more indicators in future studies.

Analytical Framework

Figure 3 shows a representation of the analytical framework, including explicit quantification of the interconnections between the three resource systems. The system-of-systems under study is shown within the dotted line and includes the interlinkages between the targets and indicators of the three goals and their outputs. The outputs assessed by this framework include required volumes of water (m^3), energy (kJ), land (ha), cost in USD, and CO_2 emissions. While there are many possible system stressors, the external stressors to the Water-Energy-Food (WEF) system-of-systems chosen for focus in this study are phosphate production and climate change. The overall study goal is to compare the required resource needs for achieving different levels of the planned strategies. The food goal aims to increase production of specific crops (olives, citrus, fruits, and vegetables). The water goal aims to increase the use of desalinated and treated wastewater. The energy goal aims to increase the percentage of solar and wind energy as part of the national energy mix. It is important to quantify the relationships between these goals in order to adequately represent the final impacts on the outputs. Critical questions related to the interlinkages between goals and outputs are outlined in Fig. 3.

Food (ton)

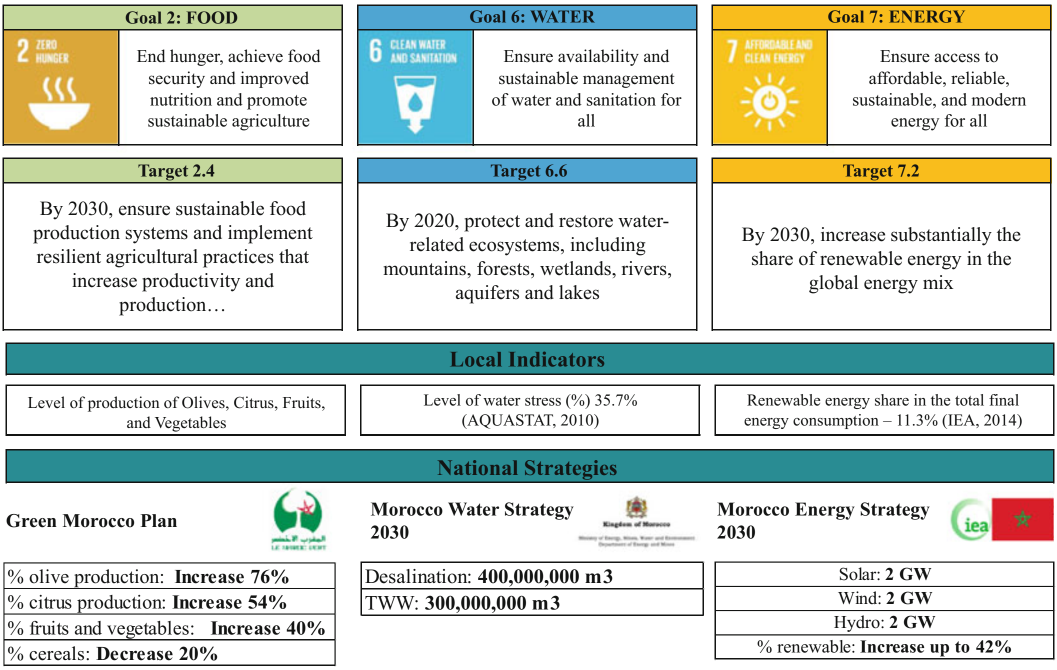
- How much water is needed to produce each crop? (m^3/ton*crop type).
  – This relates to both the water goal and the total volume of water (m^3) output.
- How much will it cost to produce each crop? (USD/ton*crop type).
- How much land does it take to produce each crop? (ha/ton*crop type).

Water (m^3)

- What percent of each source will be used (ground water, surface water, desalinated, wastewater)? (% source).
- How much energy does it take to produce each water source? (m^3/kJ).
  – Relates to both energy needed and energy output.
- How much will it cost to produce each water source? (m^3/USD).

Energy (kJ)

- What percent of each source will be used (solar, wind, fossil fuels, etc.)? (% source).
- What are the carbon emissions for each source? (CO_2/kJ).
- How much will it cost to use each energy source? (USD/kJ).
- How much water is needed to produce each energy source? (m^3/kJ).



Water-Energy-Food Sustainable Development Goals in Morocco, Fig. 2 WEF SDGs and Moroccan local indicators and strategies. (Source: Authors)

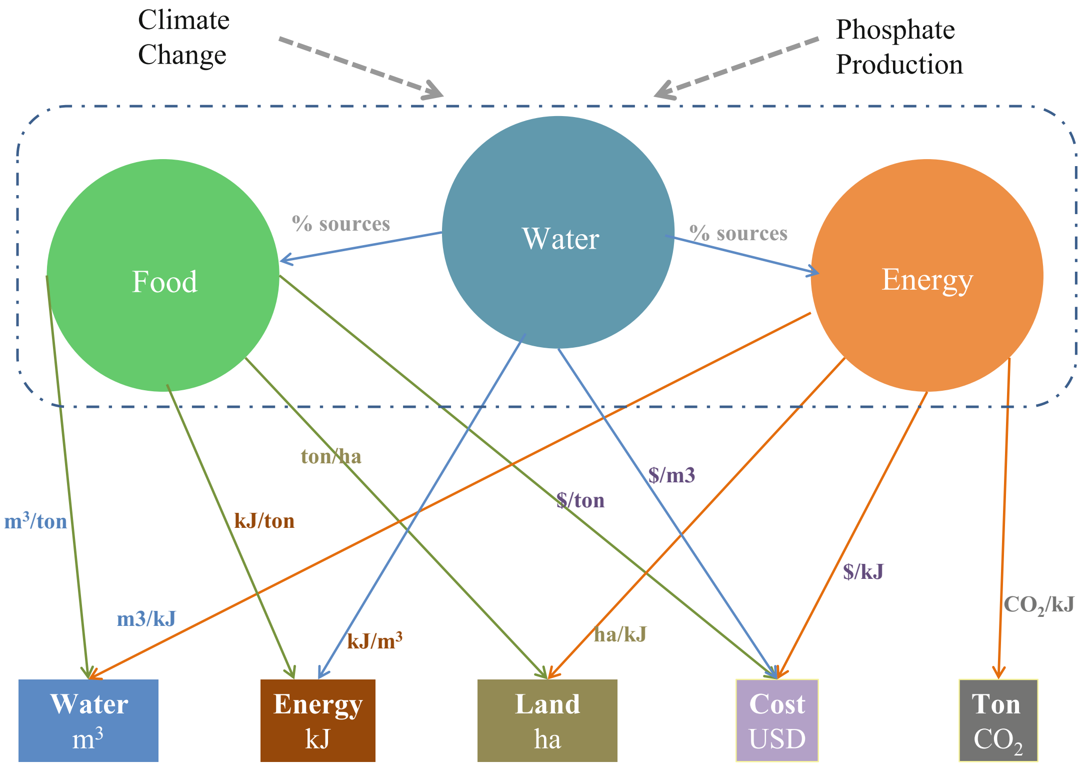
- How much landed is needed to produce each energy source? (ha/kJ).

System stressors are included by choosing low, moderate, and high conditions of climate change and phosphate production scenarios. For example, if the projected climate pressures are lower than anticipated, how would that affect the food, water, and energy resources, versus cases in which projected climate pressures are higher than anticipated.

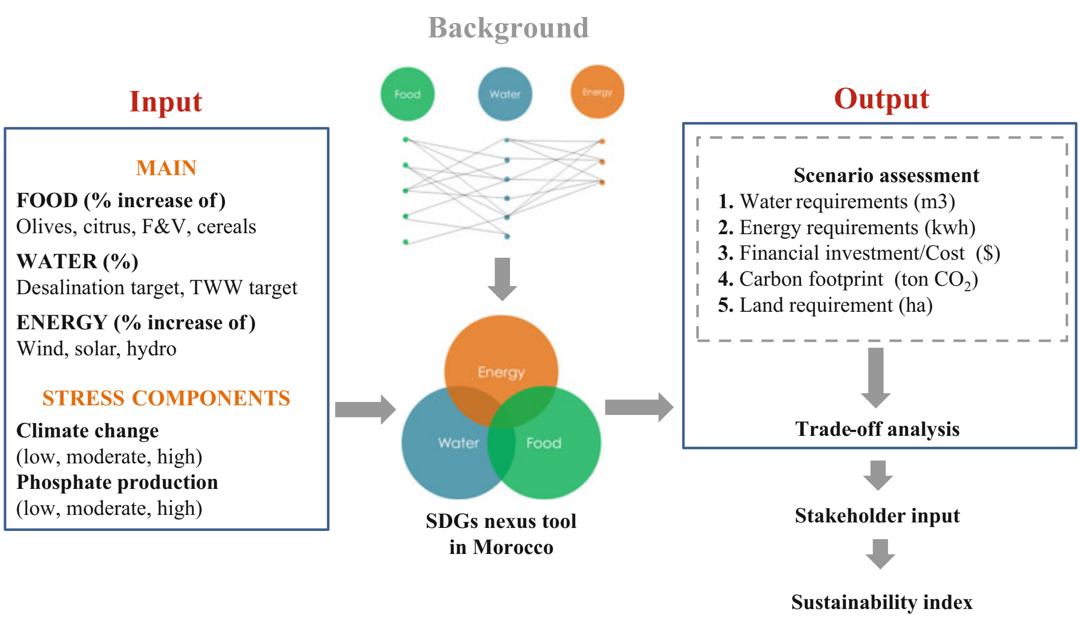
Tool Structure and Scenario Development and Evaluation

To assess the resource needs associated with various levels of implementation of the national plans and goals of the food, water, and energy resource systems, multiple scenarios are developed. Using collected baseline data for year 2012, projected resource needs for future implementation were assessed and the projected goals within the resource systems were examined together with variations of climate change and levels of phosphate production (Fig. 4).

- *Main Scenario Elements*
  1. **FOOD** – Achieving different levels of food production in accordance with the Green Morocco Plan 2020: olives (+76%), citrus (+52%), fruits and vegetables (+40%), cereals and (−21%).
  2. **WATER** – Achieving different levels of desalination and treated wastewater production, in accordance with the Morocco Water Strategy 2030: desalination (400,000,000 m^3) and treated wastewater (300,000,000 m^3).
  3. **ENERGY** – Achieving different levels of the Moroccan Energy Strategy by 2020: 2GW solar, 2GW wind, and 2GW hydro.
- *Stress Scenario Components*
  1. **Climate Change** [Low (LCC), Moderate (MCC), High (HCC)].
  2. **Phosphate Production** [Low (LPP), Moderate (MPP), High (HPP)].
- *Scenario Evaluation*
  - Water Requirement (m^3)
  - Energy Requirement (kwh)
  - Financial Investment/Cost ($)



Water-Energy-Food Sustainable Development Goals in Morocco, Fig. 3 Systems Interactions Framework. (Source: Authors)



Water-Energy-Food Sustainable Development Goals in Morocco, Fig. 4 SDGs Nexus Tool structure. (Source: Authors)

– Carbon Footprint (ton CO_2)
– Land Requirement (ha)

The tool with the governing relations and interconnections was developed in Excel. Several of the interlinkages between the water, energy, and food resource systems were taken from the WEF Nexus Tool 2.0 (Daher and Mohtar 2015).

Scenarios and Results

Base Scenario and Results

A base scenario, calculated to compare changes in resource use and competition for projected scenarios, and a "business-as-usual" approach were defined. Table 1 shows the land, water, and energy uses for selected crop types in the Green Morocco Plan (FAO 2013).

Table 2 shows the energy use and financial cost for each water source in 2012. This scenario has a **water stress** of **41.7%.**

Table 3 shows the land use, water use, CO_2 emissions, and financial cost for 2012. This scenario has an energy independence of 1%.

Scenarios with Varying Levels of Achieving National Targets for Food, Water, and Energy

Table 4 shows the percent change of resources from the base scenario and the percent breakdown of resource allocation. The scenarios in this section achieve 25%, 50%, 75%, and 100% of the water, energy, and food strategies under moderate climate change and phosphate production conditions. The last scenario achieves 100% of each strategy under high climate change and phosphate production conditions.

Figure 5 shows the percent increase required for each of the resources, relative to the base scenario.

Figure 6 shows the breakdown of resources among different sectors, and demonstrates the resource competition between the three goals. As a higher percentage of the planned goal is achieved, energy uses more water (shown by the increasing proportion of water used for energy). In the last scenario (100% of targets achieved, high phosphate use, high climate change), the proportion of water used for food production jumps up due to the increase in water use needed for irrigation as precipitation decreases. As the percentage of achieving a strategy increases, or under high impact climate change stress, the competition between food and energy for water use is exacerbated.

At the lowest level of achieving the strategies, water is the largest user of energy; as we move toward achieving a larger portion of the set strategies, food takes an increasing portion of total energy used. Even though desalination and wastewater treatment are both very energy intensive processes, overall, the desalination and wastewater treatment goals are relatively low when compared to the percentage increase of food and energy goals. Therefore, as the percentage of achieving the strategies increases, the use of resources by water becomes less significant in respect to the other goals.

This is especially obvious in the financial figures. The percent use of financial requirements for water *does* increase as the percent targets achievement increases. However, the change is minimal compared to the financial use by energy. In part, this is because Morocco does not have to build as many plants for desalination and wastewater treatment in order to begin producing more. As for energy, there is a much larger initial financial investment. For the scenario in which 100% of the strategies are achieved, renewable energy will account for almost 42% of total energy use. At 100%, nonconventional water sources will account for 6.5% of total water use. Compared to energy, the financial requirement for water is minimal.

The negative percent change in land for food is due to the *decrease* in cereal production. Since less cereals are produced, the overall food goal uses *less* land than the 2012 base scenario. This is important: it shows that in choosing to produce less cereals, Morocco is decreasing its food security, but also freeing resources to be used in other sectors, such as energy.

Water-Energy-Food Sustainable Development Goals in Morocco, Table 1 Top produced food products in Morocco with their local land, water, and energy use

Crop	Production (ton)	Land use (ha)	Water use (m3)	Energy use (kJ)
Olive	1,315,794	878,278	1,819,397,722	1.80925E+13
Orange	961,738	45,568	283597320.7	2.7774E+12
Tangerine	877,111	48,350	250218499.5	2.36134E+12
Lemons and limes	27,278	2506	9860829.178	7,464,186,023
Apple	485,642	28,713	284321478.1	1.03756E+12
Banana	222,267	4897	43872100.17	2.52535E+11
Strawberry	139,683	3011	17129900.67	1.6145E+11
Apricots	122,405	11,090	102,053,196	1.98347E+11
Figs	102,694	46,284	322117700.4	7.45362E+11
Tomatoes	1,219,071	14,187	62600138.81	9.25574E+11
Onions, dry	855,764	27,600	94445756.77	2.57601E+12
Melons	717,602	19,034	4521053.907	2.21648E+11
Carrots and turnips	707,316	12,940	142890708.6	6.1666E+11
Watermelon	574,859	12,844	22599944.22	3.9985E+11
Wheat	3,878,000	2,850,480	948534260.9	3.99067E+13
Barley	1,201,388	1,717,429	0	4.4062E+13
Maize	90,221	107,017	287161924.1	3.70709E+12
SUM	13,498,833	5,830,237	4,695,322,534	1.1805E+14

Water-Energy-Food Sustainable Development Goals in Morocco, Table 2 Water profile, energy use, and financial cost

	Volume (m3)	Energy use (kJ)	Financial cost (USD)
Surface water	8,251,000,000	4.45554E+12	165,020,000
Groundwater	2,322,000,000	2.0898E+12	208,980,000
Treated wastewater	70,000,000	1.72485E+11	21,000,000
Desalinated	7,000,000	1.008E+11	8,400,000
SUM	10,650,000,000	6.81862E+12	403,400,000

−25%–50%–75%–100% of Water, Energy, and Food National Targets (with 0% Change for Cereals)

The following graph is identical to the scenarios above *except* that there is *no* percentage change for cereal production relative to 2012. Keeping cereal production constant demonstrates how much more resources are required for the increased production of olives, citrus, and fruits and vegetables under the Green Morocco Plan (Fig. 7). Specifically, even with a 0% cereal change, the competition for resources changes: while there is an *increase* in water use, energy use, and land use, there is no longer a *negative* change in any of these resources, even though there is more competition.

As the percentage of the strategies achieved increases, more water use is transferred to the energy goal. However, the proportion going toward energy is less than in the scenario with the cereal production decrease. In the 100% scenario, with moderate climate change, and moderate phosphate production, the percent of water for energy declines from 25% to 22.7%. Under 100% strategy achievement scenario, high climate change, and high phosphate change, the water for energy percent declines from 18% to 16.2%. In both of these, the first number is with cereal production change, and the second one reflects no

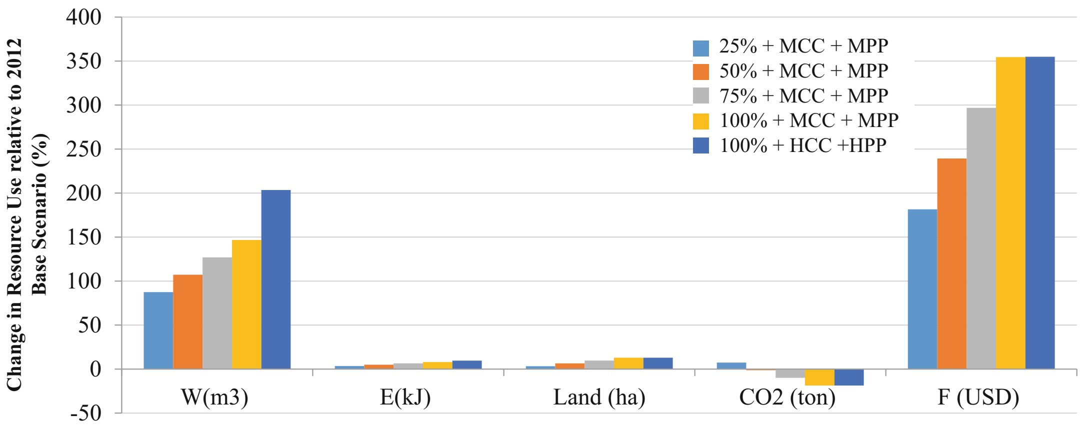
Water-Energy-Food Sustainable Development Goals in Morocco, Table 3 Moroccan energy mix

TPES	Production (GWh)	Water use (m3)	Land use (ha)	Financial cost (USD)	CO2 emissions (ton)
Oil	147,803	0	0	22,909,518,320	114,991,002
Coal	35,202	0	0	2,816,134,720	33,793,617
Biofuels and waste	16179.656	0	0	1,855,202,704	404491.4
Natural gas	12462.708	0	0	162,015,204	5520979.644
Electricity net imports	4810.168	0	0	9,031,059,376	0
Hydro	1530.508	52142402.59	22518.45	914589974.8	15305.08
Wind	655.932	151461.2581	3260.845	426554567.3	6559.32
Solar	0	0	0	0	0
SUM	218,644	52293863.85	25779.3	38,115,074,866	154731953.7

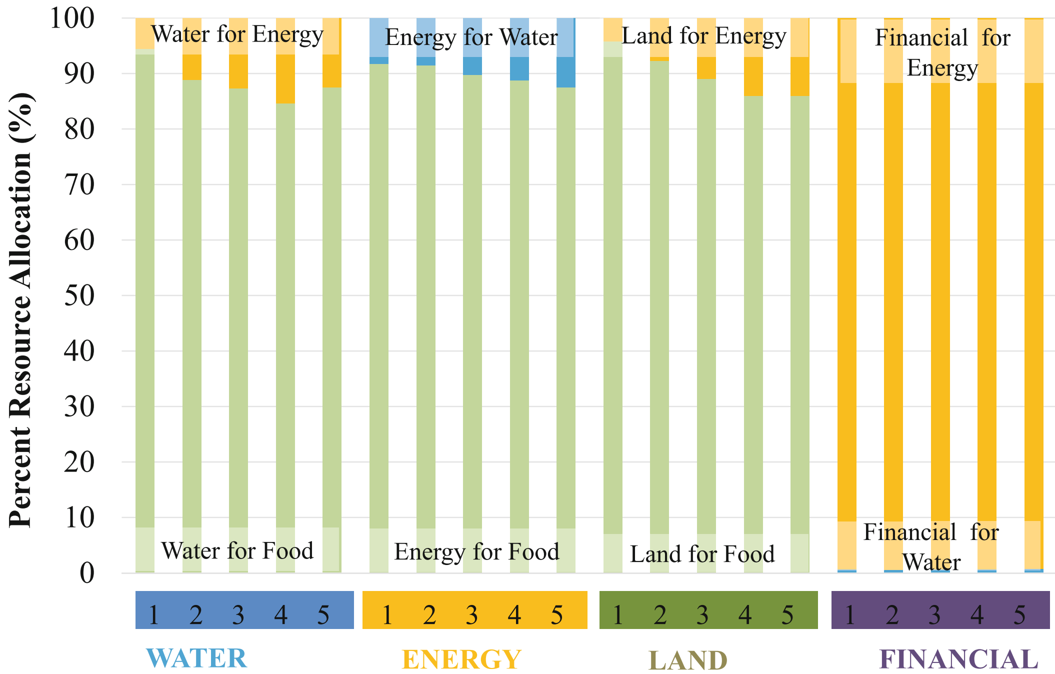
Water-Energy-Food Sustainable Development Goals in Morocco, Table 4 Outputs for scenarios of achieving 25–50–75–100% of the three targets

	25% + MCC + MPP	50% + MCC + MPP	75% + MCC + MPP	100% + MCC + MPP	100% + HCC + HPP
W (m^3)	87.42	107.19	126.96	146.73	203.46
W4F	89.50	82.88	78.31	74.98	81.96
W4E	10.50	17.12	21.69	25.02	18.04
E (kJ)	3.42	4.95	6.48	8.01	9.58
E4F	10.21	14.11	16.18	17.45	14.59
E4W	89.79	85.89	83.82	82.55	85.41
Land (ha)	3.24	6.48	9.71	12.95	12.95
L4F	−19.13	−19.13	−19.13	−19.13	−19.13
L4E	119.13	119.13	119.13	119.13	119.13
CO_2 (ton)	7.37	−1.30	−9.98	−18.65	−18.65
F (USD)	181.58	239.21	296.84	354.46	354.85
F4W	0.44	0.48	0.50	0.51	0.62
F4E	99.56	99.52	99.50	99.49	99.38
Water stress change (%)	−0.77	−2.24	−3.71	−5.19	−4.93
Energy independence change (%)	119.26	324.16	529.06	733.96	733.96

cereal production change. Having no cereal production increases competition for resources between the water, energy, and food goals. This is particularly noticeable in the food use part of Fig. 8. Since there is no decrease in cereal production, there is no decrease in land usage by the food sector. It is interesting to note, however, that as the goal percentage increases, the competition between food and energy does not change. The land usage of these two sectors increases proportionally, therefore, there is no percent change among the different scenarios. Nevertheless, the competition between these two has drastically increased from the previous scenarios that included negative cereals production. The resource allocation for the energy use is also significantly different with the cereal production change. With cereal production decrease, water is the biggest user of energy. With no cereal production change, food is now the biggest user of energy. Part of this can be attributed to the small goal percent increase in the water sector versus the large increase in the food sector for the goal targets. There is no change in the CO_2 emissions or



Water-Energy-Food Sustainable Development Goals in Morocco, Fig. 5 Outputs for scenarios of achieving 25–50–75–100% of the three strategies

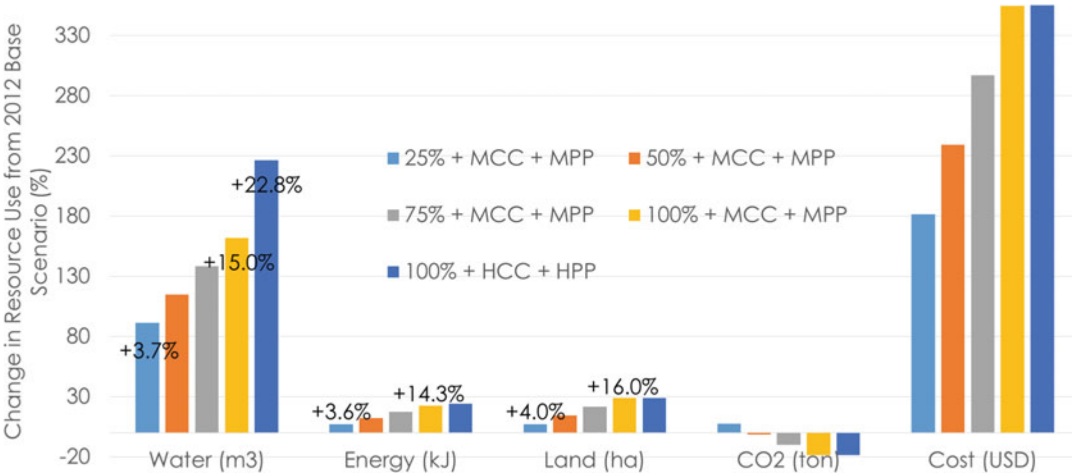


Water-Energy-Food Sustainable Development Goals in Morocco, Fig. 6 Breakdown of additional resource needs based on 2012 base scenario

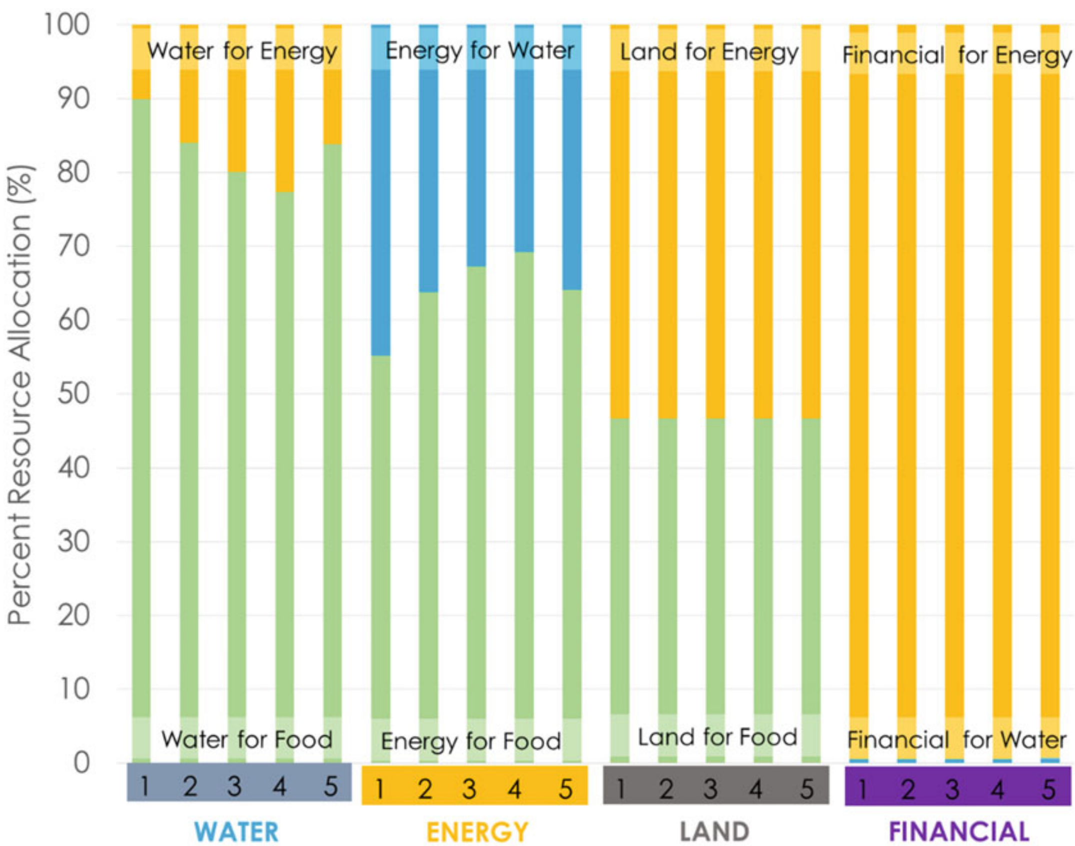
in the financial use because food did not directly contribute to those resources in this study.

No RE Versus Full Solar Versus Full Hydro Versus Full Wind

This set of scenarios compares the way in which each of the renewable energy sources competes for each of the resources. One hundred percent of the food and water goals are achieved under moderate climate change and moderate phosphate production in each scenario. The first scenario is with 0% change in renewable energy: any renewable energy currently produced stays the same. The second scenario achieves the 6 GW goal, all



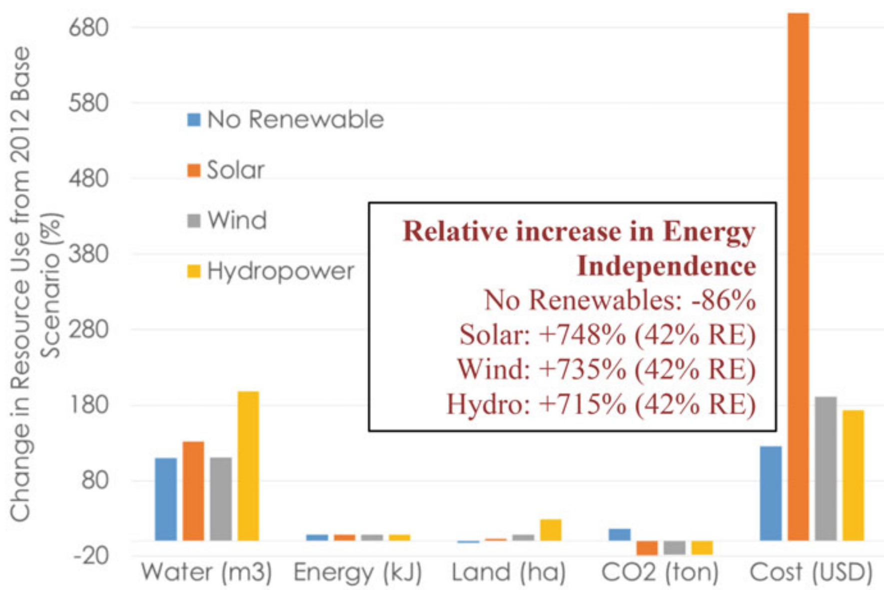
Water-Energy-Food Sustainable Development Goals in Morocco, Fig. 7 Outputs for scenarios achieving 25–50–75–100% of the three strategies (without cereals reduction)



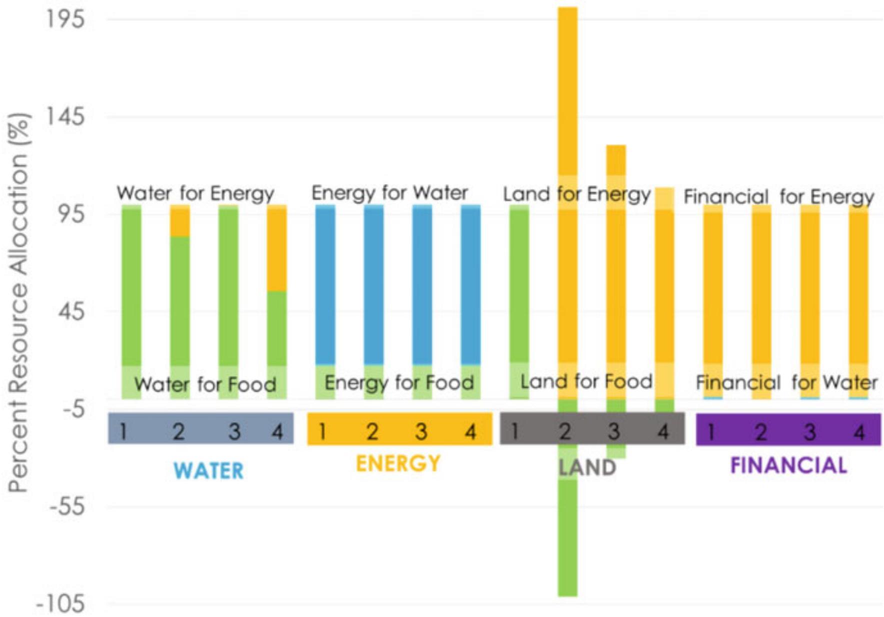
Water-Energy-Food Sustainable Development Goals in Morocco, Fig. 8 Breakdown of additional resource needs based on 2012 base scenario from solar energy. The third and fourth scenarios achieve the 6 GW goal totally from wind and hydropower, respectively.

Figure 9 shows the percent change in resource needs relative to the 2012 base scenario. Solar uses the most land and financial resources, while hydropower requires the most water. The change in CO_2 emissions is about the same between the three types of renewable energy. The inset shows the energy independence change from the base for each scenario. Achieving 42% renewable energy use substantially improves Morocco's energy independence. The slight differences in each of the renewable energy scenarios are due to the initial amount of that energy source used in accordance with the 2012 base scenario. Solar energy has the biggest energy independence percent increase from base because there is no solar energy production in 2012, while hydropower and wind power both have some energy production in 2012. The trade-off between these scenarios is the need for more resources (water, land, and money), while decreasing carbon emissions and increasing energy independence. Increasing energy independence is particularly important for Morocco, since they currently import more than 95% of their energy.

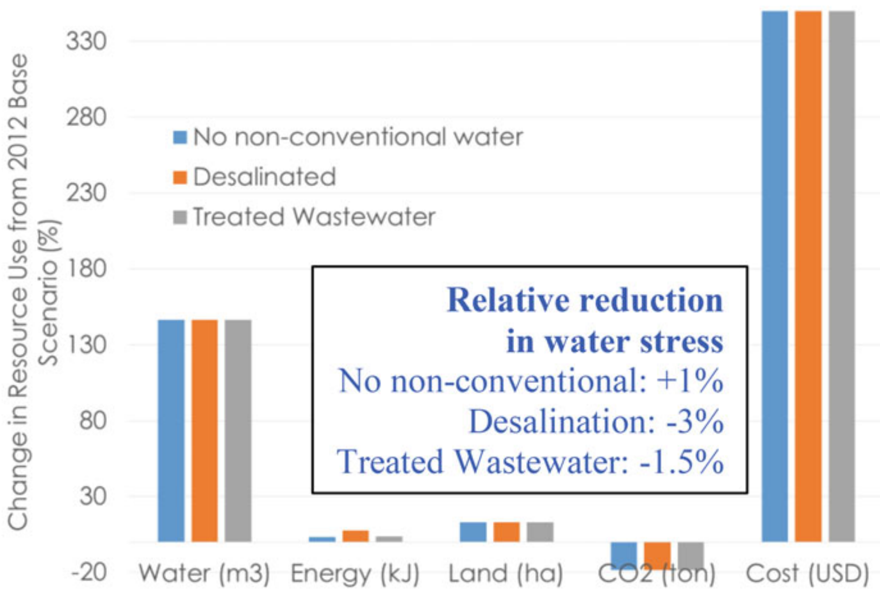
Figure 10 shows the resource breakdown and allocation under different scenarios. This graph has some of the same conclusions as Fig. 10: solar has the greatest land and financial requirements; hydropower uses the most water. This graph more clearly demonstrates the resource competition between each sector for each scenario. The land portion is a little tricky, since there is a negative land use change in the food goal due to a decrease in cereal production. The land use change in scenario 1, which has no renewable energy change, is completely due to the food goal: it uses 100% of the resource change. The solar scenario uses the least amount of land (ha/kWh), thus, the food goal contributes more to the change in land use. The hydropower scenario uses the most amount of land, so the food goal contributes less to the overall change in land use, and the wind scenario is in the middle of those two. In all the scenarios, the financial cost by the water sector is significantly less than the energy sector, but the most costly solar scenario completely dominates the financial use in the resource allocation. This indicates that the water



Water-Energy-Food Sustainable Development Goals in Morocco, Fig. 9 Outputs of scenarios relying totally on non-renewables, solar, wind, or hydro



Water-Energy-Food Sustainable Development Goals in Morocco, Fig. 10 Breakdown of additional resource needs based on 2012 base scenario

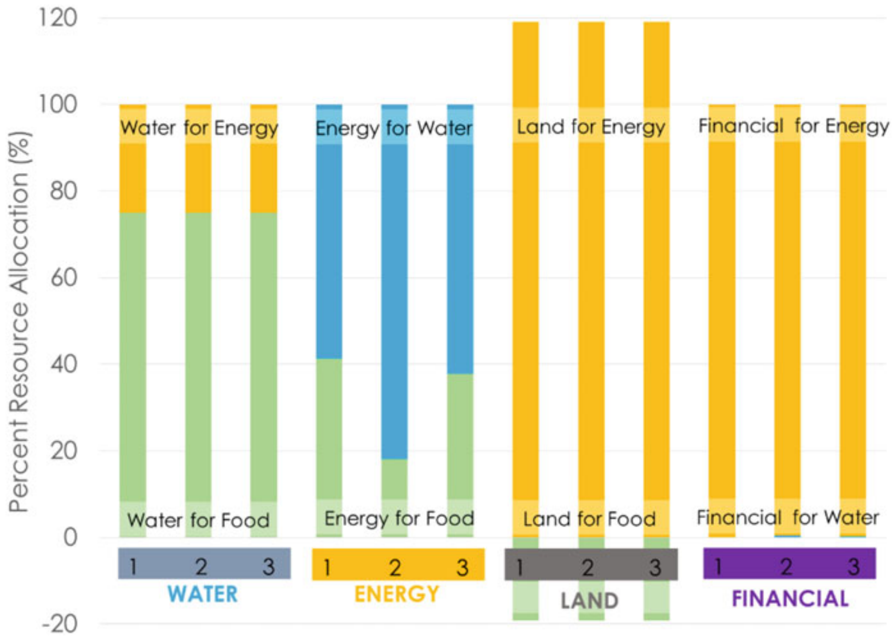


Water-Energy-Food Sustainable Development Goals in Morocco, Fig. 11 Outputs for scenarios representing different water profiles

sector competes with solar energy for financial resources. There is no change in the energy resource use because the change in renewable energy does not alter how much energy is used.

No Nonconventional Versus Full Desalination Versus Full Treated Wastewater Targets

Figures 11 and 12 illustrate the difference between achieving 0% of the water strategy and achieving



Water-Energy-Food Sustainable Development Goals in Morocco, Fig. 12 Breakdown of additional resource needs relative to 2012 base scenario

100% of the desalinated water and treated wastewater targets. This set of scenarios compares desalinated vs. treated wastewater vs. no change. The food and energy goals are assumed to be fully achieved (100%), with moderate climate change and moderate phosphate production conditions. Figure 11 shows the percent change from 2012 base scenario. Desalination uses more energy than treated wastewater and is the more costly, but compared to the differences in resources needed for achieving food and energy sector strategies, their change is minimal. The inset shows the percent change in water stress relative to the 2012 base scenario. The differences between desalination and treated wastewater results from different production values in 2012. The trade-off here focuses mainly on investing more financial and energy resources, while decreasing water stress.

Figure 12 shows no change in the water and land use, because the water goal does not directly impact these resources. Desalination has the highest conflict with the food sector in energy use. Treated wastewater uses a higher proportion of energy than the no nonconventional water scenario, but the competition here is not as significant as the desalination target. Desalination also has the highest financial cost of the three scenarios, but they are all nominal compared to the financial use by the energy sector. The important takeaway from this is that achieving 100% of the renewable energy goal requires significant financial investment, which will compete heavily with achieving other goals.

Discussions of Trade-Offs

Overall Comments on Scenarios and Trade-Offs Analysis

After looking at three strategies in Morocco and their interactions under different scenarios, the following trade-offs were observed:

- **Food:** *(–) security, financial (+) water, land, energy.*

  With regard to the Green Morocco Strategy, projected reduction in produced cereal frees resources for use in other strategies, perhaps renewable energy deployment and urban expansion. Such reduction makes additional water, land, and energy available for other strategies. Analysis of scenarios with full implementation of the three plans, while keeping the production of cereals at 2012 levels, puts additional strain on water, land, and energy resources. While the reduction in cereals production will lead to greater food dependency, it carries the benefit of freeing resources to improve energy and water security.

- **Water:** *(+) reduced water stress (−) energy, financial, land.*

  Investment in expanded desalination and wastewater treatment capacity for municipal and industrial sectors relieves water stress from one side, but does so at high energy and financial costs: both energy and food strategies require additional water. The available projection models indicate that climate change has a great impact on rainfall and results in the need for more irrigation water, which exerts additional stresses on the water system. The projected aggressive expansion in phosphate production also exerts additional stress on the water system. Allocating available water, conventional and nonconventional, across water thirsty goals is a primary, critical question to address. The availability of that water could be a major limiting factor of the extent to which the food and energy targets are fully realized, as long as the investment and costs associated with increasing existing capacity outweighs the benefits from that investment.
- **Energy:** *(+) security, emissions (−) financial, land, water.*

  Even though Morocco faces water challenges as it moves toward implementing its future goals, it remains very highly reliant on energy imports to meet increasing energy demands. This poses a security concern as well as an economic concern. Most of the electricity Morocco consumes is imported from Spain and Algeria. In 2012, the government started a program to subsidize electricity, making it more affordable to consumers and absorbing any price shocks. These high subsidies put additional strain on the national budget. The government is faced with the trade-off between investing in renewable energy sources (which requires large financial, land, and water resources), or allocating those resources to greater subsidies while continuing to rely on energy imports. In the short term, there is a high cost associated with this investment, yet over the longer term, it is expected to result in overall savings and to bring positive impacts in terms of reduced carbon emissions and additional energy security.

Importance of Capturing Spatial and Temporal Attributes and Identifying Hotspots

Identifying the aggregate resources required for the different strategies tells only part of the story. Without looking at the spatial and temporal distribution of the resources available and identifying the areas of greatest demand for them, an important piece of the analysis remains missing. There might not be strong competition for land between food and renewable energy strategies: the majority of agricultural activity takes place in the north, while the greatest potentials for wind and solar exist in the south. The lack of sufficient water for new renewable sources of energy in the south might results in a hotspot. Another hotspot might surface in areas of high phosphate activity, where water might not be available. The next step needs to build on the presented preliminary results and adding the spatial and temporal components to them in order to identify potential hotspots, and come up with customized recommendations for each.

Assumptions and Limitations

Throughout the study, several assumptions were made to simplify the complexity of the problem at hand. Different limitations also play a role in adding to the research complexity and uncertainties. Examples include:

– The current tool assumes linear relationships between systems, which may not reflect reality.
– The ability to ensure locally measured data (water requirements, local yields, energy requirements, etc.) would provide more refined results.

– The existing tool assesses the environmental impact of a scenario only as reflected in its carbon emissions: no calculations are yet incorporated to quantify effects on water and soil quality.

Conclusions

This preliminary study highlights the interactions between three targets within the Water, Energy, and Food Sustainable Development Goals in Morocco. Main conclusions include:

- **Clear competition** exists between achieving different national strategies for water, energy, land, and financial resources.
- Morocco's strategy to **reallocate 20% of land currently used for cereal production to grow other crops** reduces potential stresses on land and water resources, reflecting Morocco's choice to accept less self-sufficiency in cereals, in order to allocate those resources to other areas, mainly renewable energy.
- **Investing in renewable energy** carries in the short term, high capital and running costs and considerable local water use; still, it provides Morocco with a higher level of energy security and carbon dioxide reduction. In the long-term, it releases strain from the Moroccan budget because a substantial portion of the current budget is allocated to energy imports and subsidies.
- The most prominent trade-off in using **desalinated water and treated wastewater** is increased energy use versus decreased stress on Morocco's already dwindling water supply. The need for alternative sources of water is amplified under different climate change scenarios and phosphate production scenarios.
- There is a need to better understand the extent of the stresses on the different resources and trade-offs once the **spatial and temporal components** of the resources and hotspots are captured.
- More targets and indicators exist under SDGs 2, 6, and 7; these will clearly have tight interconnections and potential competitions: there is a need to **expand study to further targets**.
- **SDGs offer an important framework** and structure for goals toward which nations can work in order to improve different social, economic, and environmental indicators (Arora and Mishra 2019). Nevertheless, the SDGs and set of underlying targets are generic, therefore:
  1. The **indicators** needed to assess progress toward these targets must be put in a local context that reflects local strategies and plans, and be based on locally collected data.
  2. The **targets and respective indicators are interconnected**, and can compete with one another. Therefore, depending on the local context and national plans, the right mix of targets and the extent to which a country needs to strive toward achieving those targets must be brought into a local/national context.

Cross-References

▶ Integrated Water Resource Management
▶ Water Footprint
▶ Water Planning
▶ Water Research and Innovation Partnership Addressing Sustainable Development Goals
▶ Water Resources
▶ Water Resources Assessment
▶ Water Resources Management
▶ Water Sources

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