Scenario catalog to quantify the potential change in water resources and ecosystem services in Israel and the West Bank.

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1 Introduction

The Mediterranean water resources may be subjected to water scarcity problems due to specific climatic conditions (i.e., precipitation patterns) and due to increased water consumption as a result of economic growth and population increase. Scenario analysis is a useful tool to uncover the impact of external developments and support stakeholders in decision making by revealing the impact of certain management options. In the course of the MedWater project, various scenarios on the basis of population growth and management factors shall be investigated regarding their impact on water resources and ecosystems. The following factors were defined as the key influencing factors for the national water resources:

- External factor (EF):
    - Climate change (EF1)
    - Population increase (EF2)
- Management factor (MF):
    - Quantity of desalinated water (MF1)
    - Quantity of treated waste water (MF2)
    - Quantity of abstracted groundwater from the WMA (MF3)
    - Per-Capita water demand (MF4)
    - Irrigation quantity (MF5)
    - Area allocated to agricultural and urban use (MF6)
    - Area allocated to nature (MF7)

Three explorative scenarios of external factors were initially defined on the basis of population increase. A single RCP4.5 climate change scenario is uniformly considered for all scenarios. Three narrative management scenarios, regional nature conservation, baseline and regional resources intensive, are respectively defined upon the three explorative scenarios (see Fig. 1):

- **Regional nature conservation (RNC):** The regional nature conservation scenario assumes a political focus on preserving or recovering the local state of nature and its water resources. The abstraction of water from local freshwater resources is restricted. Discrepancies in demand and supply are compensated via import of virtual water (e.g. import of food). Domestic demand is given a higher priority than agricultural and industrial demand.
- **Baseline (B):** The baseline scenario is based on currently prevailing trends, plans and policies.
- **Regional resource intensive (RRI):** The regional resource intensive scenario assumes a focus on economic growth despite the extensive damage to local freshwater resources and nature. The abstraction of water from local freshwater

resources is not restricted. Agricultural and industrial demand is given a high priority, reducing the import of virtual water.

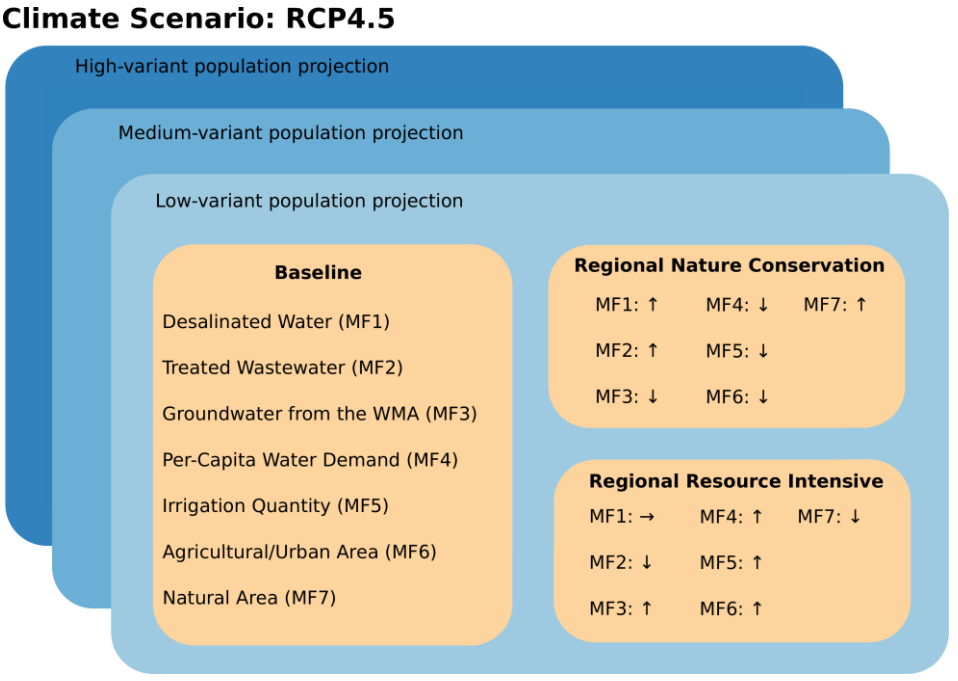

Figure 1: Conceptual framework of the scenarios; Arrows indicate the relative trend in comparison with the baseline scenario.

2 Methods

The general structure of the scenario catalog was compiled under the cooperation of all project partners and later adjusted based on input from local water authorities. For the quantification of the individual management factors input from local authorities, publicly available governmental data and published research was consulted.

3 Quantification of the external factors

3.1 Climate change (EF1)

The RCP4.5 climate change scenario shall be considered for all scenarios. A statistical down-scaled high-resolution projection of climate change provided by the Euro-Mediterranean Center on Climate Change (CMCC) shall be utilized. This projection is available on a daily time step.

3.2 Population increase (EF2)

Demographic estimates for the three explorative scenarios are based on the medium, high, low-variant projections by the United Nations (2019) (see Fig. 2 and Tab. A-1).

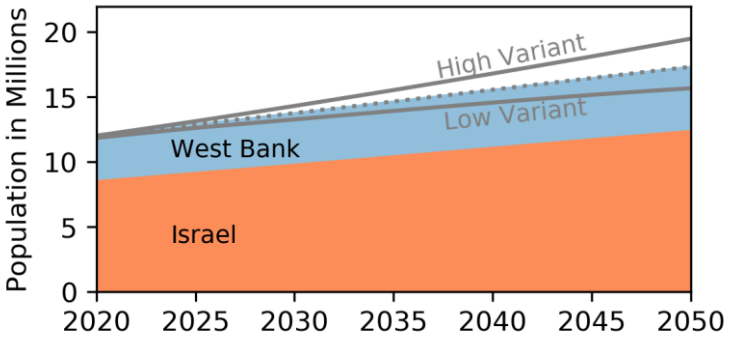

Figure 2: Projected population by region.

4 Quantification of the management factors

4.1 Quantity of desalinated water (MF1)

The recent advent of desalination in Israel has helped to partly disburden natural fresh water resources. An even greater importance will be most likely attached to desalination for the future freshwater supply. However, the discussions that lead to the implementation of desalination plants are not fully open to public scrutiny, making it challenging to estimate the future share of desalinated water. At this stage of the proceeding the Israeli government has approved to target approximately 750 – 850 MCM/a until the year 2020. The National Master Plan by the Israeli Water Authority suggests the implementation of a capacity of 1700. However, the government hasn't allocated the funds for further construction of desalination plants yet. Future periods of droughts will most likely cause the Israeli government to allocate further money to the construction of desalination plants. Current large-scale seawater reverse osmosis (SWRO) desalination plants have nearly reached the theoretical minimum energy demand that is required for the extraction of salts from the water. This is limiting a further increase of efficiency or decrease of operational costs.

The regional resource intensive scenario considers no further allocation of funds for the construction of desalination plants, reaching a desalination capacity of 880 MCM/a until the year 2050. Under the regional nature conservation scenario, a capacity of 1770 MCM/a will be reached by 2050. Whereas, the baseline scenario assumes a capacity of 1600 MCM/a by 2050 (see Fig. 3). The desalination quantity is considered to be independent of the population growth. All population increase scenarios apply the same desalination scenarios.

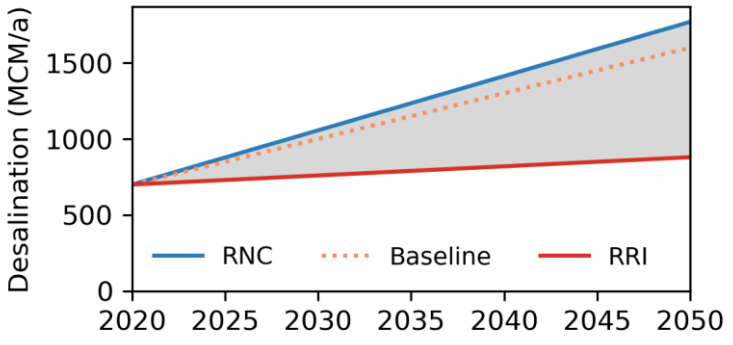

Figure 3: Quantity of desalinated water under the three management scenarios.

4.2 Quantity of treated waste water (MF2)

At present, roughly 80% of Israeli domestically consumed water is being treated and reused (Water Authority - State of Israel, 2012; Avgar, 2018) leaving only minor scope for improvement. The baseline and regional resource intensive scenarios assume a constant treatment of 80% of the domestic consumed water. In the regional nature conservation scenario 85 % of the domestic water is treated by 2050 (see Fig. 4).

In the West Bank at present roughly ~31 % of waste water is collected. Less than 10% of the collected waste water is treated. The remainder is discharged untreated into cesspits or directly into wadis. Some partially treated waste water is discharged to the environment, but none is reused for irrigation. According to the PWA Masterplan a treatment of ~60 % and a reuse of ~36 % of domestic waste water is targeted for 2032. This target very optimistic for the target date of 2032 and should therefore be considered for the best case scenario, i.e. regional nature conservation. The baseline scenario assumes that only half of the target is reached by 2032, with the target finally being met by the end year of 2050. The regional resource intensive scenario assumes that only one quarter of the target is reached by 2032, and half of the target is met by 2050. In all cases approximately 80% of domestically consumed water becomes waste water (see Fig. 4).

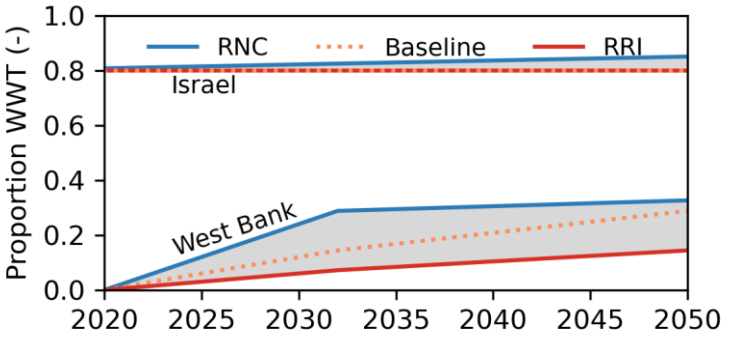

Figure 4: Proportion of treated domestic waste water.

The absolute quantity can be obtained by multiplying MF4 (Per-Capita water demand), EF2 (Population increase) and the proportional values of Figure 4. In the West Bank, the regional nature conservation scenario with high variant population projection ("RNC-high") produces the most water (see Fig. 5), since the increase of waste water treatment facilities exploits previously untreated domestic waters. Whereas in Israel a reduction of domestic consumption reduces the quantity of waste water that is available for treatment.

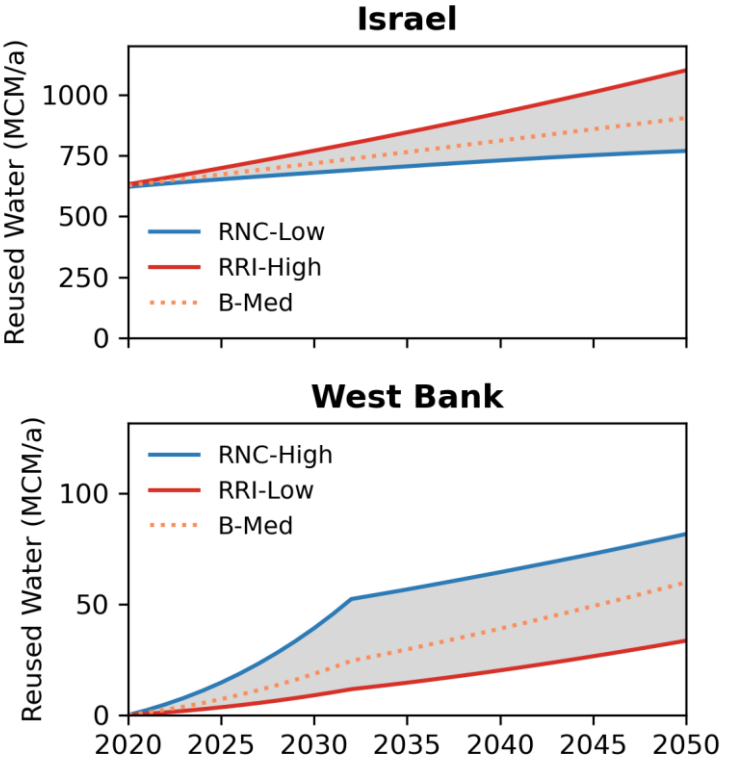

Figure 5: Quantity of treated domestic waste water.

4.3 Quantity of abstracted groundwater from the WMA (MF3)

Presently, the Israel Water Authority limits the permitted pumping volumes from the WMA to 5-year moving average of recharge. However, economic growth and population growth may increase demands and exert pressure to deviate from this strategy. In the Baseline scenario, we assume that the exceeding water demands are satisfied by other means, such as desalination and grey water, and pumping volumes are equal to the 5-year moving average. While the RRI scenario assumes a linear increase to 120% of the Baseline scenario and in the RNC scenario abstraction rates are linearly reduced to 80% of the Baseline scenario (see Figure 6).

The recharge rates of the WMA are quantified by a dual medium soil water balance model, where the precipitation and potential evapotranspiration from the RCP4.5 climate model serves as an input.

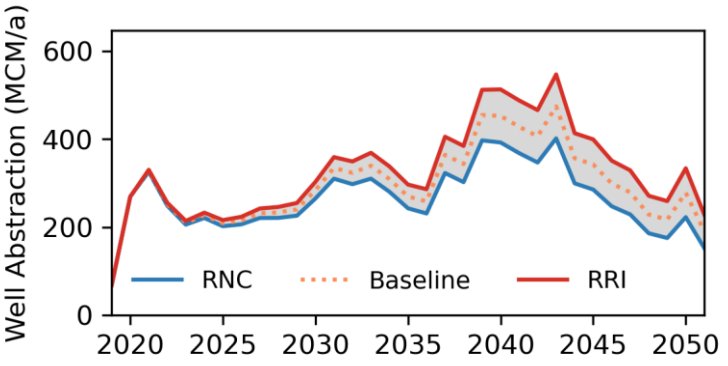

Figure 6: Groundwater abstraction from the Western-Mountain-Aquifer.

4.4 Per-Capita water demand (MF4)

The domestic per-capita water demand is presently 90 CM/a/c in Israel and 27 CM/a/c in the West Bank. The regional resource intensive scenario assumes an increase of the Israeli consumption to 100 CM/a/c by 2050. The water demand of the West Bank is set to 44 CM/a/c by 2032 and a further increase to 55 CM/a/c by 2050 in this scenario. The domestic per-capita water demand in the baseline scenario is subject to no change in Israel and to an increase to 44 CM/a/c by 2032 in the West Bank. The consumption remains stable after 2032. The regional nature conservation scenario assumes a decrease to 80 CM/a/c by 2050 in Israel and an increase to 44 CM/a/c by 2032 in the West Bank.

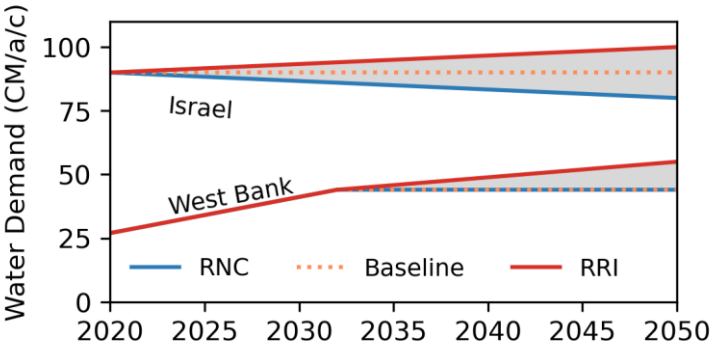

Figure 7: Domestic water demand per capita.

4.5 Irrigation quantity (MF5)

The influence of changed irrigation efficiencies is negligible in comparison to crop type or the other management factors; therefore, this management factor is changed to irrigation quantity and source instead of irrigation efficiency. This management factor is dependent on the area allocated for an agricultural area.

Currently, 25% of the agricultural area needs to be irrigated in Israel, which requires approximately 1250 MCM of water each year, and primary water sources are natural freshwater from lakes and aquifers, treated wastewater, and treated brackish water. Though the agricultural land area for the baseline scenario remains constant; therefore, the irrigation

quantity and sources remain constant by 2050. The regional nature conservation scenario assumes to decrease the agricultural land; thus, the irrigated land and irrigation water requirement decrease in the same manner. Additionally, more treated wastewater is set to use as much as possible (more wastewater will generate because of higher population growth) instead of reducing water use from the aquifers. It is assumed that this increases water storage in the aquifer, which increases natural flow in Yarkon/ Ras Al Ain and Taninim/Al Timsah springs. The regional resource intensive scenario assumes the agricultural area increases, thus irrigated land increases in the same manner. In this scenario, water use from both aquifer and treated wastewater sources are assumed to increase.

Table 4: Criteria for different scenarios for irrigated water quantity.

Scenarios		Criteria	
		Israel	**West Bank**
Baseline	Business as usual	Constant at current level	Constant at current level
RNC	regional nature conservation	More treated water and less aquifer water	Rainfed agriculture
RRI	regional resource intensive	More treated and aquifer water	More treated wastewater

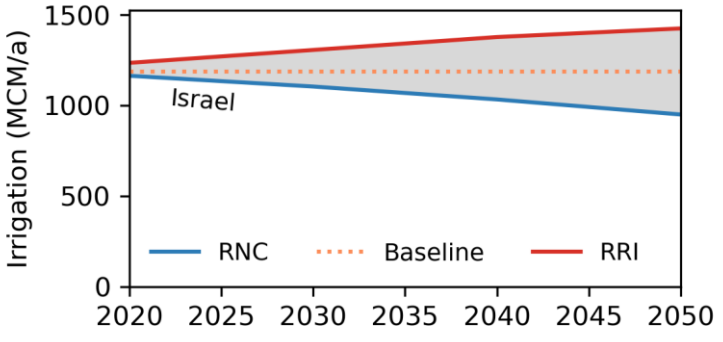

Figure 4: Irrigation quantity.

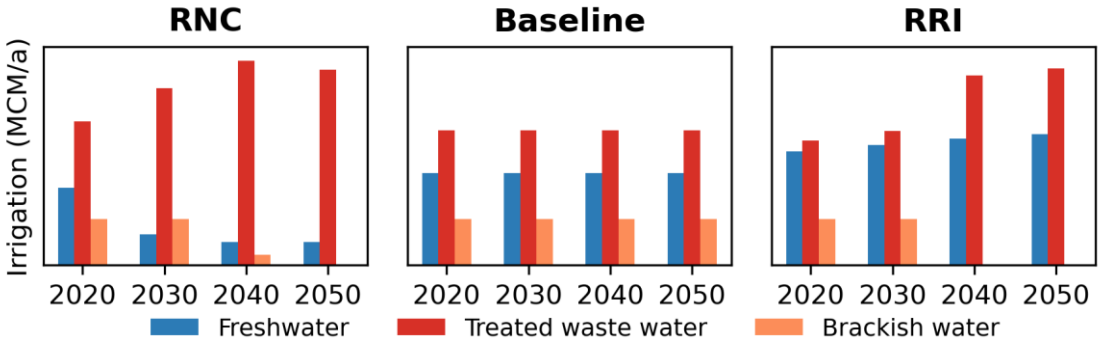

Figure 4: Volume of irrigated water as per water sources in Israel.

In West Bank, approximately 87% of the cultivated area is rainfed agriculture, and else the area is irrigated agriculture. 39.9 MCM of water is used for irrigation purposes. This water is coming from the Jordan River, Palestinian water wells and treated wastewater. The "Regional Nature Conservation" scenario assumes a constant of agricultural land; thus, 39.9 MCM of water for irrigation is enough for this scenario. In both "Baseline" and "Regional Resource Intensive" scenarios assume an increase of agricultural land area, which requires more water for irrigation. It is assuming that those extra water is coming from treated wastewater mentioned in the PWA Master plan.

4.6 Area allocated to agricultural and urban use (MF6)

Israel is using 13% (3,000 km^2) of its land area for agricultural purposes. The agricultural land area has had a decreasing trend in Israel over the last few decades. Therefore, for the baseline scenario, it is suggested to keep this land area constant by 2050. It is assumed that an increase of 1,000 km^2 of the agricultural area by 2050 in the regional resource intensive scenario and a decrease of 1,000 km^2 of the agricultural area by 2050 in the regional nature conservation scenario in Israel.

Table 1: Criteria for different scenarios for the projection of agricultural land.

Scenarios		Criteria	
		Israel	**West Bank**
Baseline	Business as usual	Remain constant at 3,000 km^2	Remain constant at 1,100 km^2
RNC	regional nature conservation	Decrease at 2,000 km^2	Remain constant at 1,100 km^2
RRI	regional resource intensive	Increase at 4,000 km^2	Increase at 1,400 km^2

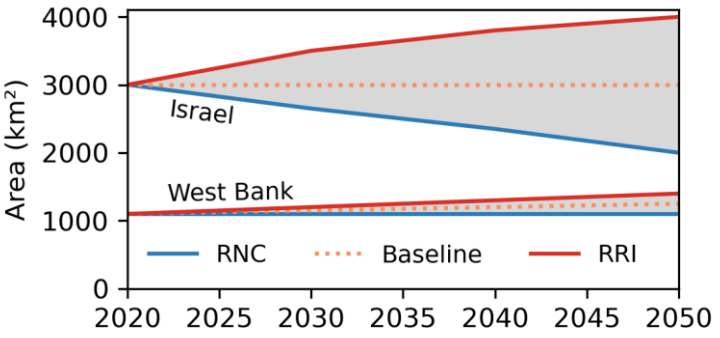

Figure 1: Agricultural area.

Palestine is using 20% (1,200 km^2) of its land for agricultural purposes. Ninety percent of agricultural lands are located in the West Bank (the area covering 5,844.5 km^2), while only 10% is located in the Gaza Strip (the area covering 365 km^2). Because of high food demand regarding the high population growth trend, the agricultural land area has had an increasing trend in West Bank. For West Bank, it is assumed that an increase of 100 km^2 of the agricultural area per 10 years by 2050 in the “Regional Resource Intensive” scenario and an increase of 50 km^2 of the agricultural area per 10 years by 2050 in the baseline scenario. And the agricultural land remains constant regional nature conservation scenario.

Israel and West Bank's territory have 10.4% (2,271 km^2) and 12.8% (788 km^2) of urban land area at present with a current population density of around 3,400 c/km^2 and 6,113 c/km^2 in urban area respectively. The regional nature conservation scenario assumes that the urban land area remains stable but increase of population density for both regions by 2050. Whereas the regional resource intensive scenario assumes that the population density remains constant, therefore, the increase of urban land area for both regions by 2050. The baseline scenario assumes the urban area increase on an average of the other two scenarios.

Table 1: Criteria for different scenarios for the projection of land area for the urban area.

Scenarios		**Criteria**	
		Israel	**West Bank**
Baseline	Business as usual	Average of RNC and RRI	Average of RNC and RRI
RNC	regional nature conservation	Constant urban area	Constant urban area
RRI	regional resource intensive	Constant population density in urban area	Constant population density in urban area

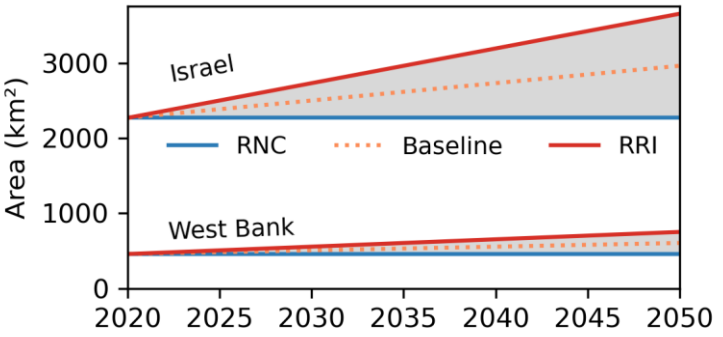

Figure 2: Urban area.

4.7 Area allocated to nature (MF7)

Currently, Israel has certain protected areas (forests, nature reserves, and national parks) for the implementation of its biodiversity policy. These protected areas often include sparsely vegetated rangelands or even large parts of the desert. For this factor in our scenarios, it is considered the planted forested (reforestation and new forest) areas as land for nature, which will be changed while other protected areas remain the same. According to the afforestation program, Israel is, on average, increasing the forest area by 11 km^2 every year since 1990 (Kaplan, 2011). Therefore, Israel has 1,150 km^2 of a planted forest in 2017. The baseline scenario it is suggested to follow this afforestation program. In the regional nature conservation scenario, we assume 0.2 km^2 of forest area per 1,000 persons, as it is today and required for sustainable development in Israel. Therefore, the forest area increases according to the number of populations. In the regional resource intensive scenario assumes no further increase of forest land.

In the Palestinian territories, the forest land is significantly decreasing in recent years, and it has only 101 km^2 forest land presently. According to the Fifth national report (2015), the current decreasing rate of deforestation is 0.82% per year, but the decreasing rate will be lower at 0.2% per year by 2020. Therefore, a 0.2% per year decreasing rate is considered a baseline scenario. Whereas, 0.82% decreasing rate is assumed as the regional resource intensive scenario. In the regional nature conservation scenario is assumed no further decrease of forest land, if possible, then increase.

Table 3: Criteria for different scenarios for the projection of land area for nature.

Scenarios		Criteria	
		Israel	West Bank
Baseline	Business as usual	Afforestation of 11 km^2 each year	Decrease at 0.2%
RNC	regional nature conservation	0.2 km^2 per 1000 people	Constant at current area
RRI	regional resource intensive	Constant at the current area	Decrease at 0.82%

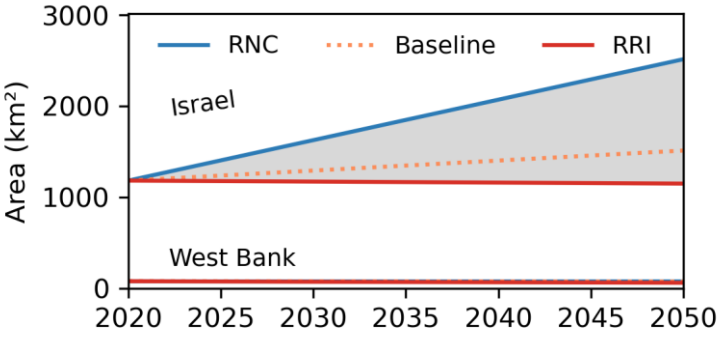

Figure 3: Area allocated to nature.

Resources

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Appendix

A External factors

Table A-1: Population increase (EF2)

Year	Israel (Million people)			West Bank (Million people)			Total (Million people)		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
2020	8.64	8.71	8.78	3.19	3.22	3.22	11.83	11.93	12.00
2025	9.16	9.35	9.54	3.44	3.52	3.58	12.60	12.87	13.12
2030	9.64	9.98	10.33	3.62	3.76	3.97	13.26	13.75	14.30
2035	10.12	10.63	11.14	3.79	4.01	4.38	13.91	14.64	15.52
2040	10.58	11.28	11.98	3.97	4.26	4.81	14.55	15.54	16.79
2045	11.02	11.94	12.86	4.12	4.51	5.24	15.15	16.44	18.10
2050	11.41	12.58	13.78	4.24	4.73	5.69	15.65	17.31	19.47

B Management factors

Table B-1: Overview of all management factors

Management factors	Regional nature conservation	Baseline	Regional resource intensive
Desalinated water (MF1)	Based on the recommended quantity of the national Master plan (1750 MCM/a by 2050)	Based on the minimum recommended quantity to meet the demand reliably (1600 MCM/a by 2050)	Commissioning of currently approved capacity (885 MCM/a by 2030)
Treated waste water (MF2)	Israel: Increase to (85%) West Bank: Increase to 29% by 2032 and to 33% by 2050	Israel: Proportion of treated waste water remains at current levels (80%) West Bank: Increase to 14% by 2032 and to 29% by 2050	Israel: Proportion of treated waste water remains at current levels (80%) West Bank: Increase to 8% by 2032 and to 14% by 2050
Abstracted groundwater from the WMA (MF3)	Reduced groundwater abstraction (-10%) to achieve an optimal spring discharge to maintain ecosystem services	Based on the mean annual recharge of the preceding 7 years	Increased abstraction rates (+10%) under an optimized spatial distribution of wells
Per-Capita water demand (MF4)	Israel: Decrease to 80 CM/a/c by 2050 West Bank: Increase to 44CM/a/c by 2032, then stagnant	Israel: Stagnant at present levels 90 CM/a/c by 2050 West Bank: Increase to 44 CM/a/c by 2032, then stagnant	Israel: Increase to 100CM/a/c by 2050 West Bank: Increase to 44 CM/a/c by 2032, then further increase to 55 CM/a/c by 2050
Irrigation quantity (MF5)	Overall decrease of irrigation quantity (950 MCM/a by 2050) and a shift towards the use of treated waste water as a source	Irrigation quantity remains at current levels (1188 MCM/a) and their sources remain the same	Overall increase of irrigation quantity (1425 MCM/a by 2050) and a shift towards the use of treated waste water and freshwater as a source
Agricultural and urban area (MF6)	Israel: Decrease to 4,000 km^2 by 2050 West Bank: Decrease to 800 km^2 by 2050	Israel: Remain constant at 5,000 km^2 West Bank: Remain constant at 1,100 km^2	Israel: Increase to 6,000 km^2 by 2050 West Bank: Increase to 1400 km^2 by 2050
Natural area (MF7)	Israel: 0.2 km^2 per 1000 people by 2050 West Bank: Constant at current level	Israel: Afforestation of 11 km^2/a West Bank: Decrease at 0.2%/a	Israel: Constant at the current level West Bank: Decrease at 0.82%/a

Quanitity of desalinated water (MF1)

Table B-2: Desalinated water.

Year	Israel (MCM/a)		
	RNC	B	RRI
2020	700	700	700
2025	878	850	730
2030	1057	1000	760
2035	1235	1150	790
2040	1413	1300	820
2045	1592	1450	850
2050	1770	1600	880

Quantity of treated waste water (MF2)

Table B-3: Quantity of treated waste water under the regional nature conservation scenario.

Year	Israel (MCM/a)			West Bank (MCM/a)		
	Low	Medium	High	Low	Medium	High
2020	622.32	627.38	632.43	0.00	0.00	0.00
2025	653.14	666.50	679.86	14.08	14.41	14.65
2030	680.41	704.60	728.79	35.73	37.18	39.22
2035	706.37	742.04	777.72	49.16	51.96	56.71
2040	730.76	778.96	827.37	53.26	57.21	64.50
2045	752.41	814.72	877.97	57.26	62.60	72.80
2050	769.69	848.11	929.17	60.89	67.91	81.72

Table B-4: Quantity of treated waste water (MF2) under the baseline scenario.

Year	Israel (MCM/a)			West Bank (MCM/a)		
	Low	Medium	High	Low	Medium	High
2020	622.32	627.38	632.43	0.00	0.00	0.00
2025	659.63	673.12	686.62	7.04	7.21	7.32
2030	694.14	718.82	743.50	17.86	18.59	19.61
2035	728.43	765.22	802.01	28.05	29.65	32.36
2040	762.01	812.27	862.75	36.32	39.01	43.98
2045	793.73	859.46	926.19	44.97	49.17	57.18
2050	821.83	905.57	992.11	53.73	59.92	72.10

Table B-5: Quantity of treated waste water (MF2) under the regional resource intensive scenario.

Year	Israel (MCM/a)			West Bank (MCM/a)		
	Low	Medium	High	Low	Medium	High
2020	622.32	627.38	632.43	0.00	0.00	0.00
2025	671.87	685.61	699.36	3.52	3.60	3.66
2030	719.83	745.42	771.01	8.93	9.29	9.80
2035	768.90	807.73	846.57	14.61	15.44	16.85
2040	818.48	872.47	926.69	20.18	21.67	24.43
2045	867.19	939.01	1011.91	26.55	29.02	33.75
2050	913.14	1006.18	1102.35	33.58	37.45	45.06

Quantity of abstracted groundwater from the WMA (MF3)

Table B-6: Quantity of abstracted groundwater from the WMA (MF2)

Year	Israel & West Bank (MCM/a)		
	Baseline	RNC	RRI
2020	68	68	68
2021	269	269	269
2022	328	326	330
2023	252	249	256
2024	210	206	214
2025	227	221	233
2026	209	202	216
2027	215	206	223
2028	232	221	242
2029	233	221	246
2030	240	226	255
2031	284	265	303
2032	335	310	359
2033	323	298	349
2034	340	310	369
2035	309	280	338
2036	270	243	297
2037	259	231	286
2038	364	323	406
2039	343	302	385
2040	455	397	512
2041	453	393	513
2042	428	368	488
2043	407	347	466
2044	475	402	547
2045	357	299	414
2046	343	285	400
2047	299	247	351
2048	279	229	329
2049	229	186	271
2050	217	175	259

Water demand per capita (MF4)

Table B-7: Water demand per capita.

Year	Israel (CM/a/c)			West Bank (CM/a/c)		
	RNC	B	RRI	RNC	B	RRI
2020	90.00	90.00	90.00	27.00	27.00	27.00
2025	88.33	90.00	91.67	34.08	34.08	34.08
2030	86.67	90.00	93.33	41.17	41.17	41.17
2035	85.00	90.00	95.00	44.00	44.00	45.83
2040	83.33	90.00	96.67	44.00	44.00	48.89
2045	81.67	90.00	98.33	44.00	44.00	51.94
2050	80.00	90.00	100.00	44.00	44.00	55.00

Irrigation quantity (MF5)

Table B-8: Projection for the sector-wise allocation of the irrigated water quantity in Israel.

Year	Baseline (MCM/a)			RNC (MCM/a)			RRI (MCM/a)		
	NFW	TWW	BW	NFW	TWW	BW	NFW	TWW	BW
2020	400	588	200	337	627	200	494	541	200
2030	400	588	200	133	771	200	523	584	200
2040	400	588	200	100	889	44	551	827	0
2050	400	588	200	100	850	0	570	855	0

NFW: Natural Freshwater, TWW: Treated Wastewater, BW: Brackish water

Table B-9: Projection for the allocation of the required irrigated land area and water quantity in Israel.

Year	Irrigated area (km^2)			Irrigated Water requirement (MCM/a)		
	Baseline	RNC	RRI	Baseline	RNC	RRI
2020	1250	1225	1300	1188	1164	1235
2030	1250	1163	1375	1188	1104	1306
2040	1250	1088	1450	1188	1033	1378
2050	1250	100	1500	1188	950	1425

Irrigated area = 25% of the total agricultural land
Irrigated water requirement = 0.95 vol/area

Area allocated to agricultural and urban use (MF6)

Table B-10: Projection for the allocation of the agricultural land area for Israel and the West Bank.

Year	Israel (km^2)			West Bank (km^2)		
	Baseline	RNC	RRI	Baseline	RNC	RRI
2020	3000	3000	3000	1100	1100	1100
2030	3000	2650	3300	1150	1100	1200
2040	3000	2350	3700	1200	1100	1300
2050	3000	2000	4000	1250	1100	1400

Table B-11: Projection for the allocation of the urban area for Israel and the West Bank.

Year	Israel (km^2)			West Bank (km^2)		
	Baseline	RNC	RRI	Baseline	RNC	RRI
2020	2271	2271	2271	459	459	459
2030	2502	2271	2733	508	459	557
2040	2773	2271	3195	557	459	655
2050	2964	2271	3567	606	459	753

Table B-12: Projection for average population density in the urban area for Israel and the West Bank.

Year	Israel (people/km^2)			West Bank (people/km^2)		
	Baseline	RNC	RRI	Baseline	RNC	RRI
2020	3627	3835	3440	6626	7015	6277
2030	3859	4395	3440	7112	8196	6277
2040	4065	4967	3440	7490	9285	6277
2050	4244	5539	3440	7802	10301	6277

Area allocated to nature (MF7)

Table B-13: Projection for the allocation of the forest area for Israel and the West Bank.

Year	Israel (km^2)			West Bank (km^2)		
	Baseline	RNC	RRI	Baseline	RNC	RRI
2020	1183	1183	1183	78.3	78.3	78.3
2030	1293	1627	1172	76.7	78.3	71.9
2040	1403	2072	1161	75.2	78.3	66.0
2050	1513	2516	1150	73.7	78.3	60.6