SUSTAINABILITY OF THE GEDIZ BASIN-TURKEY: A WATER – ENERGY AND FOOD NEXUS APPROACH

by

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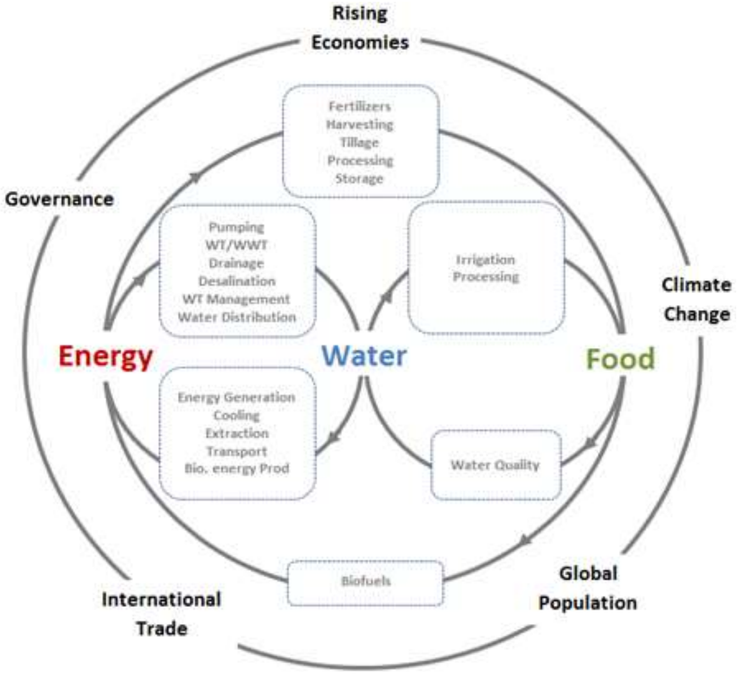
OBJECTIVE

to determine the water and energy tradeoffs to the food production and the development of forward looking scenarios that ensure the optimal use of these resources

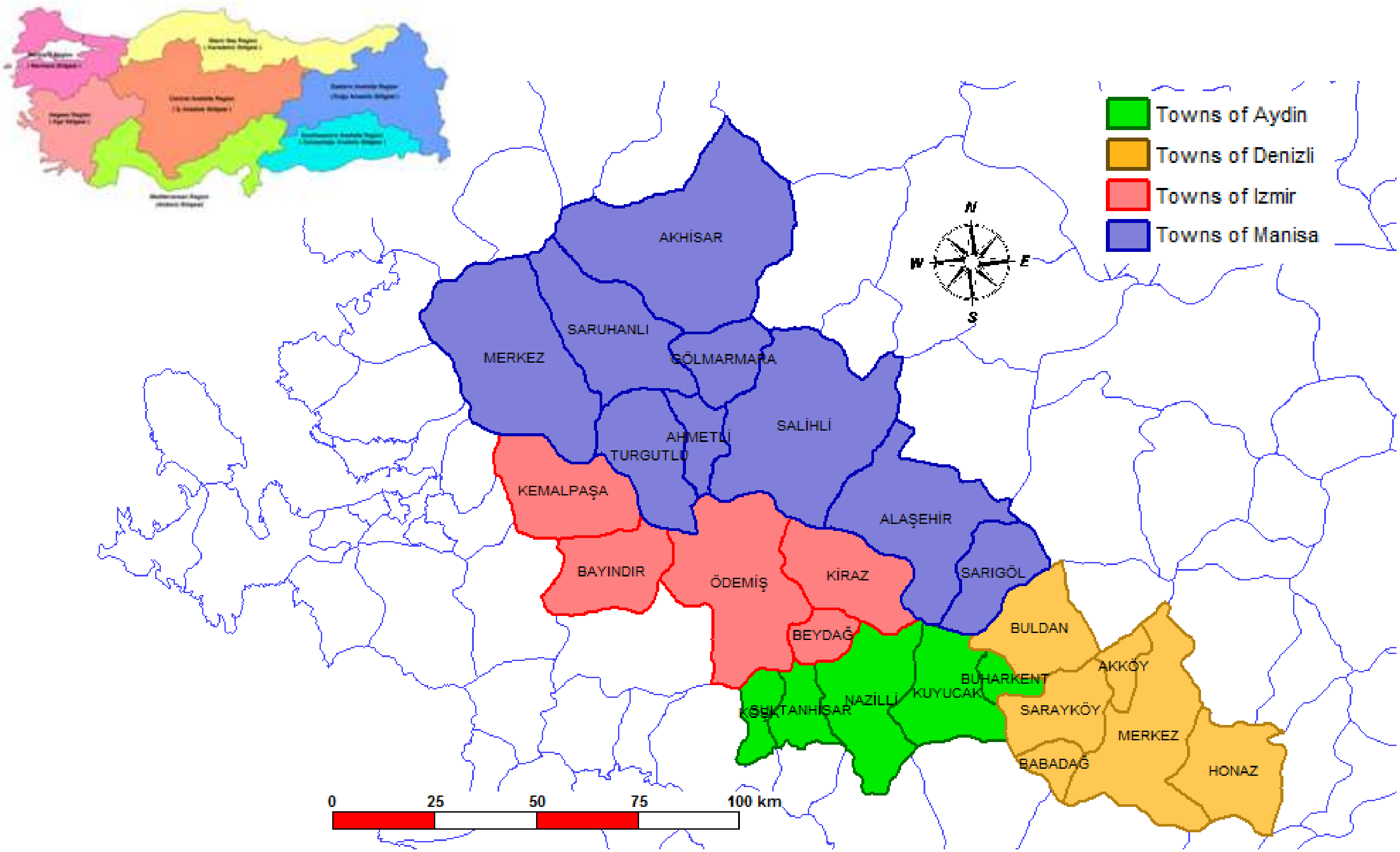


(Mohtar, Daher, 2012)

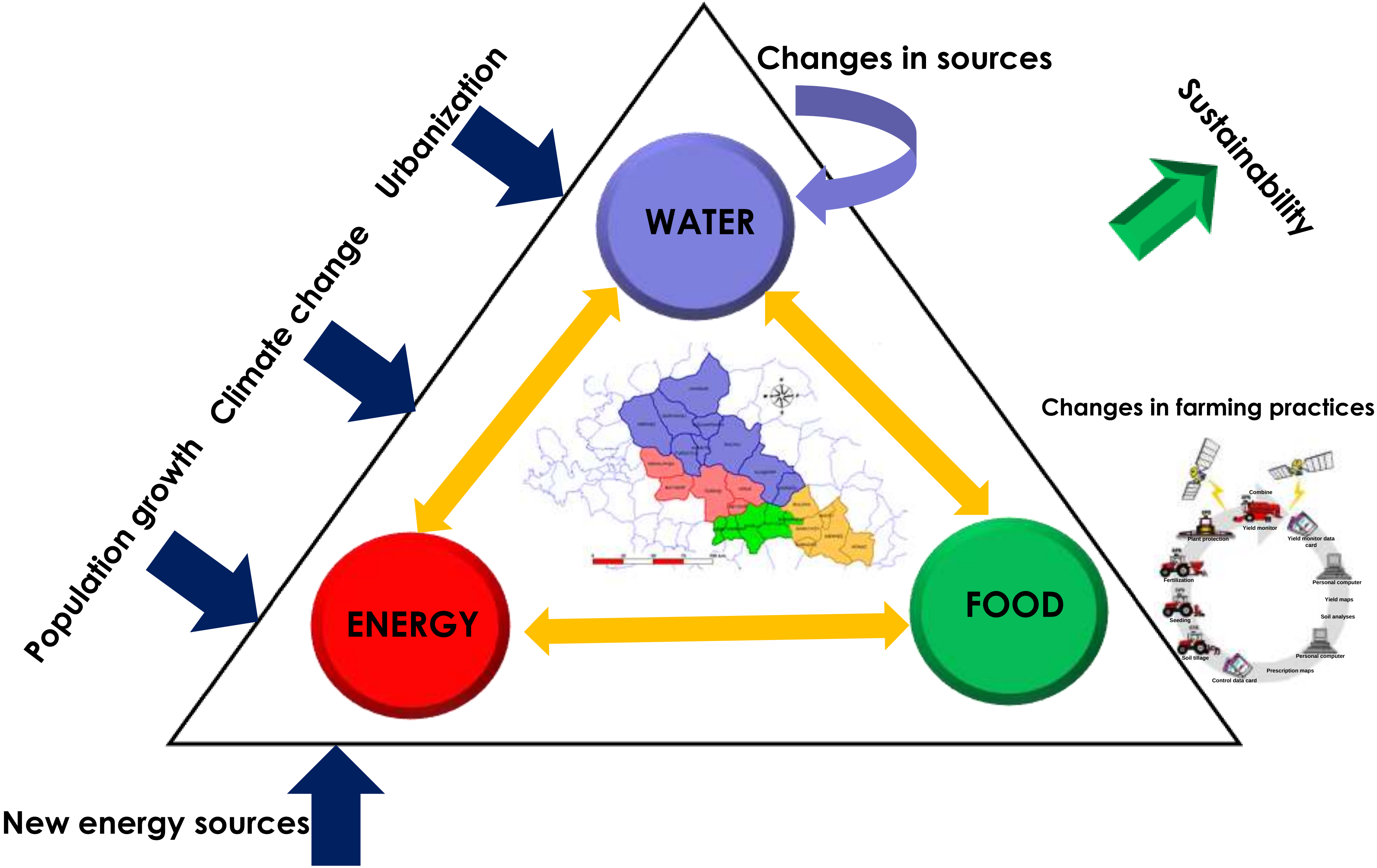
QUESTIONS & ANSWERS

- What is the current status of the Gediz Basin?
- What are the input and output relations?
- Which crops govern the basin?
- How climate change and urbanization along with the changes in technologies and sources will affect the sustainability?
- Will the farming and crop production be sustainable in the future?

LOCATION OF THE BASIN

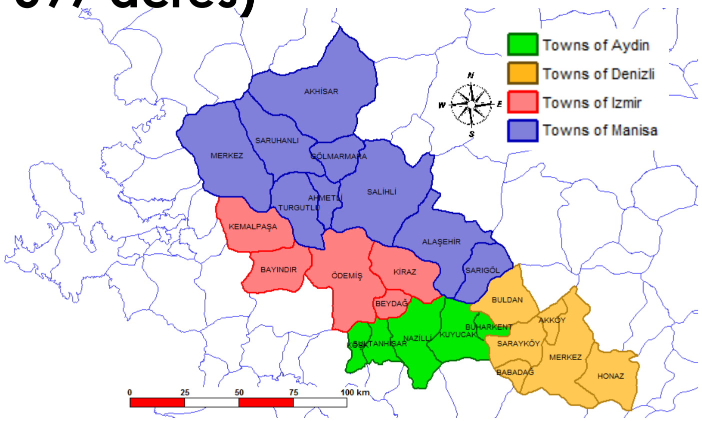


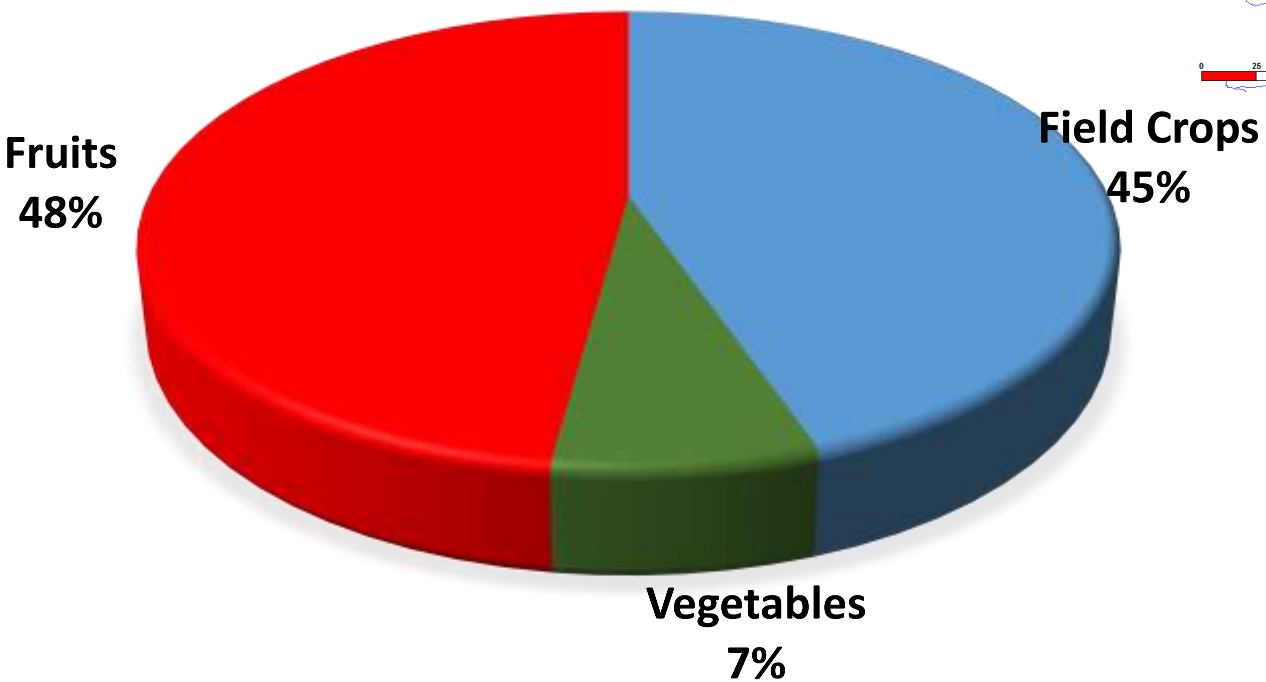
FRAMEWORK


Urbanization
Climate change
Population growth
Changes in sources
Sustainability
WATER
ENERGY
FOOD
Changes in farming practices
Combine
Yield monitor
Plant protection
Yield monitor data card
Fertilization
Personal computer
Yield maps
Soil analyses
Seeding
Soil tillage
Personal computer
Prescription maps
Control data card
New energy sources

LAND SIZE AND DISTRIBUTION (TIE-2014)

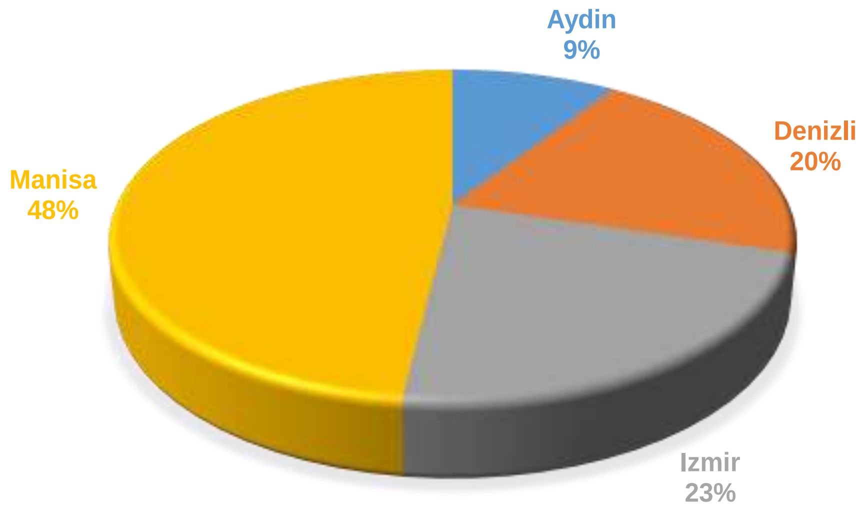
Total Land size for production: 613917.2 ha (1 519 597 acres)





FIELD CROPS (31)

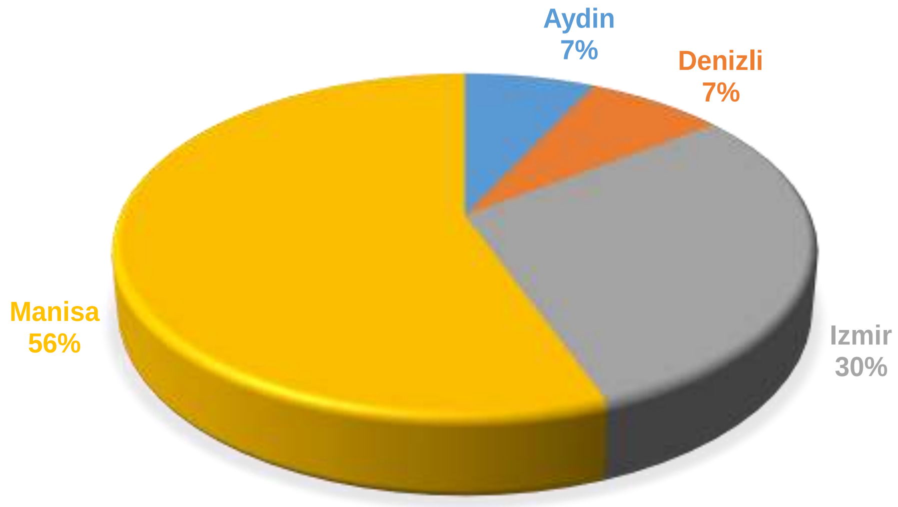
Total Land size for field crops: 274490.8 ha



Barley
Beans (Dried)
Beans for table
Chick pea
Clover
Corn
Corn for silage
Cotton
Groundnut
Horse bean
Italian ryegrass
Lenox
Lentil
Oat
Oat (green)
Poppy
Potato
Rye
Sesame
Sorghum (green)
Sugarbeet
Sunflower
Sweet pea
Tobacco
Trefoil
Triticale (grain)
Triticale (grass)
Vetch
Vetch (Burcak)
Vetch (green)
Wheat

VEGETABLES (39)

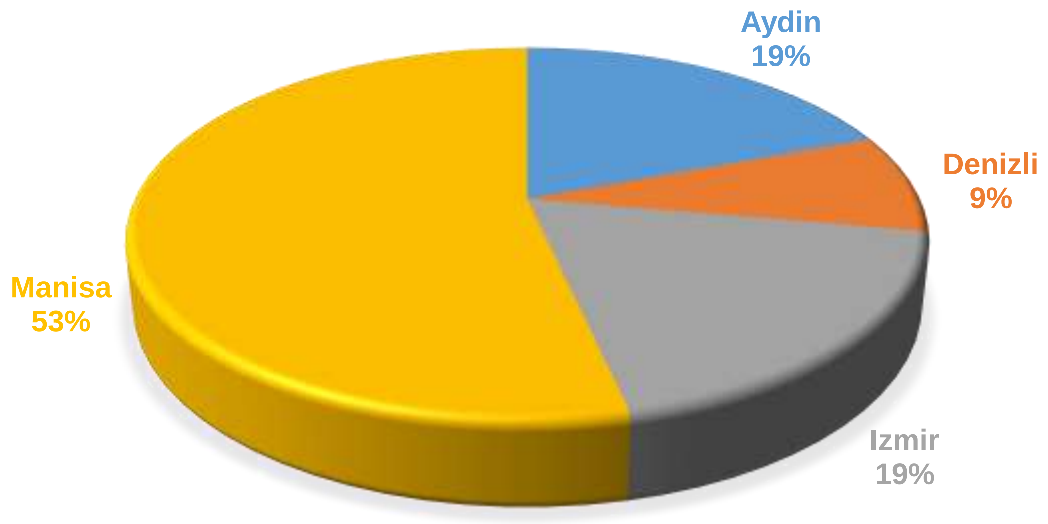
Total Land size for vegetables: 45505.6 ha



- X- Beans dried
- X- Broccoli
- X- Cabbage
- X- Calavence
- X- Carrot
- X- Cauliflower
- X- Celery
- X- Cucumber
- X- Dill weed
- X- Eggplant
- X- Fresh beans
- X- Fresh beans
- X- Fresh mint
- X- Garlic (dried)
- X- Garlic (fresh)
- X- Green pepper
- X- Hairy cucumber
- X- Horse Beans fresh
- X- Kidney beans (dried)
- X- Kidney beans (fresh)
- X- Leek
- X- Lettuce
- X- Melon
- X- Okra
- X- Onion (Dried)
- X- Onion (fresh)
- X- Parsley
- X- Pumpkin
- X- Radish
- X- Red beet
- X- Rocket
- X- Spanich
- X- Swisschard
- X- Tomato
- X- Turnip
- X- Watermelon
- X- Zucchini squash
- X-Artichoke
- X-Cress

FRUITS (25)

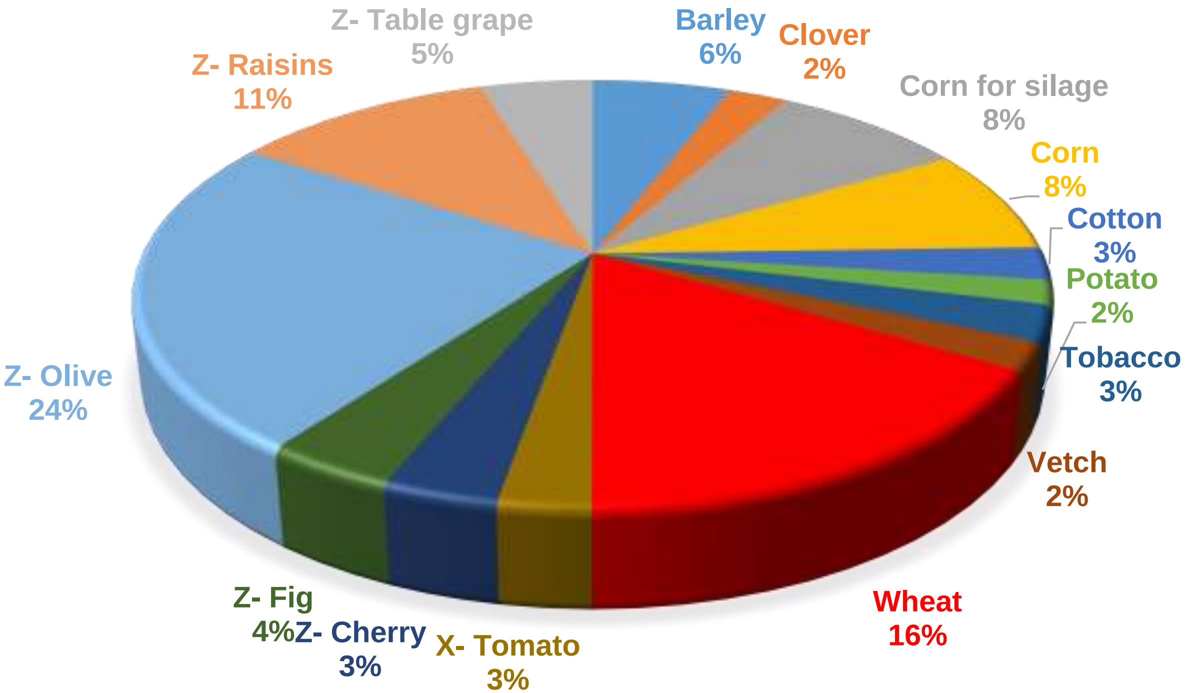
Total Land size for vegetables: 293920.8 ha

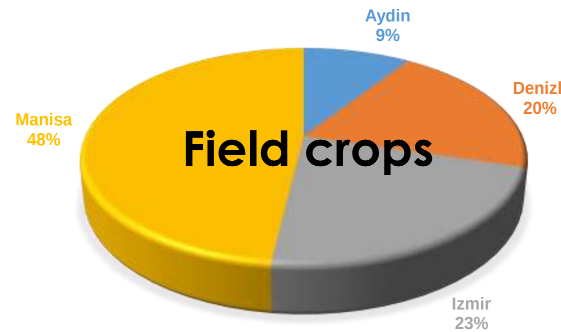


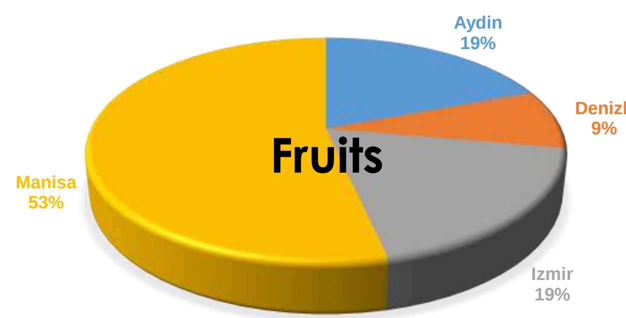
- Z- Almond
- Z- Aniseed
- Z- Apple
- Z- Apricot
- Z- Blackberry
- Z- Cherry
- Z- Chestnut
- Z- Fig
- Z- Mandarin
- Z- Olive
- Z- Orange
- Z- Peach
- Z- Pears
- Z- Persimmons
- Z- Pistachio
- Z- Plum
- Z- Pomagranate
- Z- Quince
- Z- Raisins
- Z- Sourcherry
- Z- Strawberry
- Z- Table grape
- Z- Thyme
- Z- Vineyard
- Z- Walnut

CROPS GROWN (top fifteen)

Determined by sorting data in terms of land allocation and water requirement







TOWN BASED CROP PRODUCTION (Barley example)

Town	Production Area (ha)	Total production (tons)	Yield (t/ha)	Tractor Use (h/ha)	Average Tractor power (kW)
Buharkent	78.5	220	2.80	13.1	29.66
Köşk	50	185	3.70	13.1	34.15
Kuyucak	700	2,656	3.79	13.1	30.64
Nazilli	827.2	2,979	3.60	13.1	32.93
Sultanhisar	40	131	3.28	13.1	29.1

TRACTOR RUN TIME (Barley example)

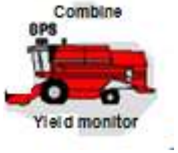
13.1 h/ha

DIESEL CONSUMPTION

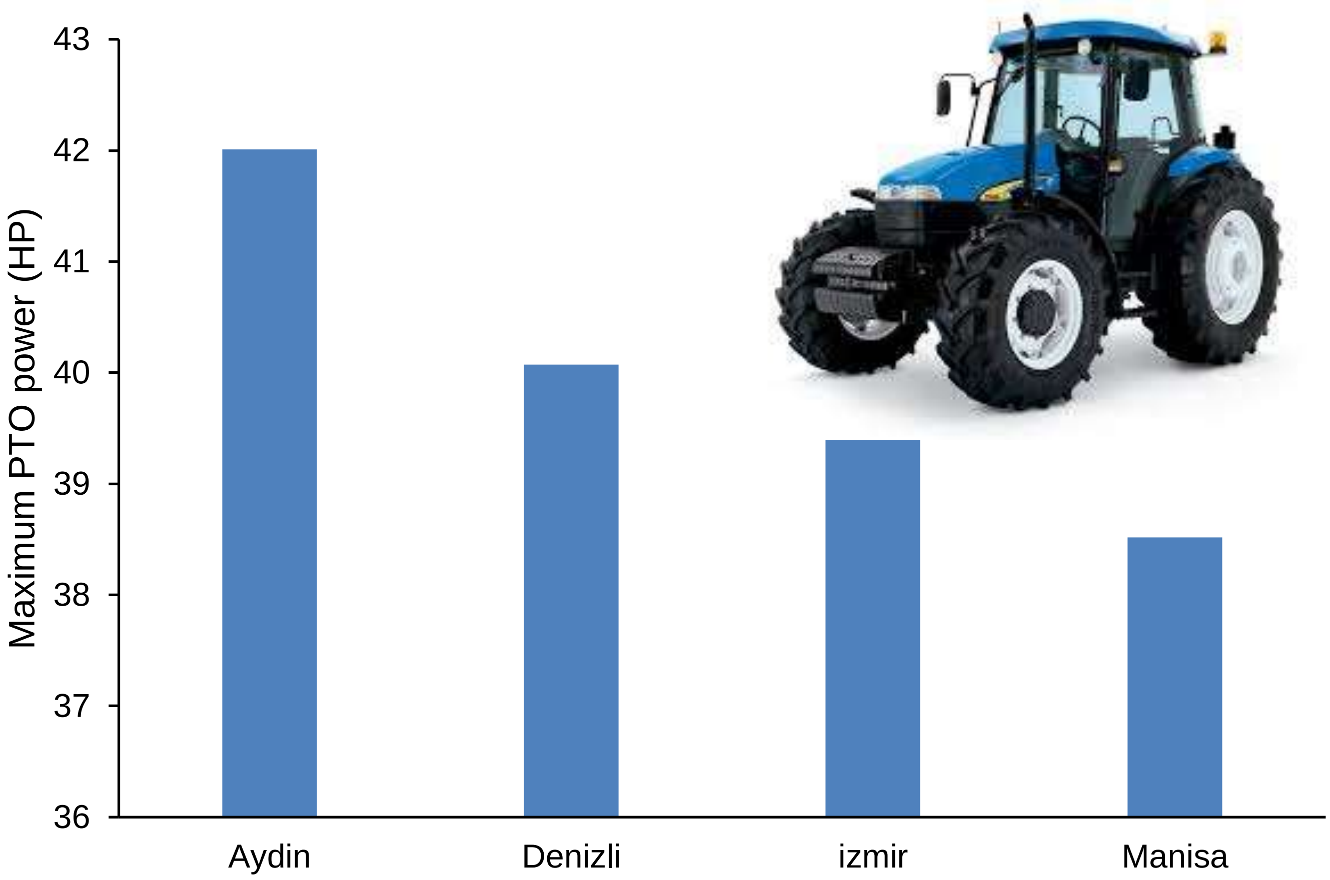
$$Q_{avg} = 0.223 \, . \, P_{pto}$$

Qavg = average diesel fuel consumption (L/h)
P_{pto} = the rated PTO power, kW

Consumption (L) = Q x Time spent per ha



TRACTOR POWER DISTRIBUTION IN TOWNS



TRACTOR DIESEL CONSUMPTION

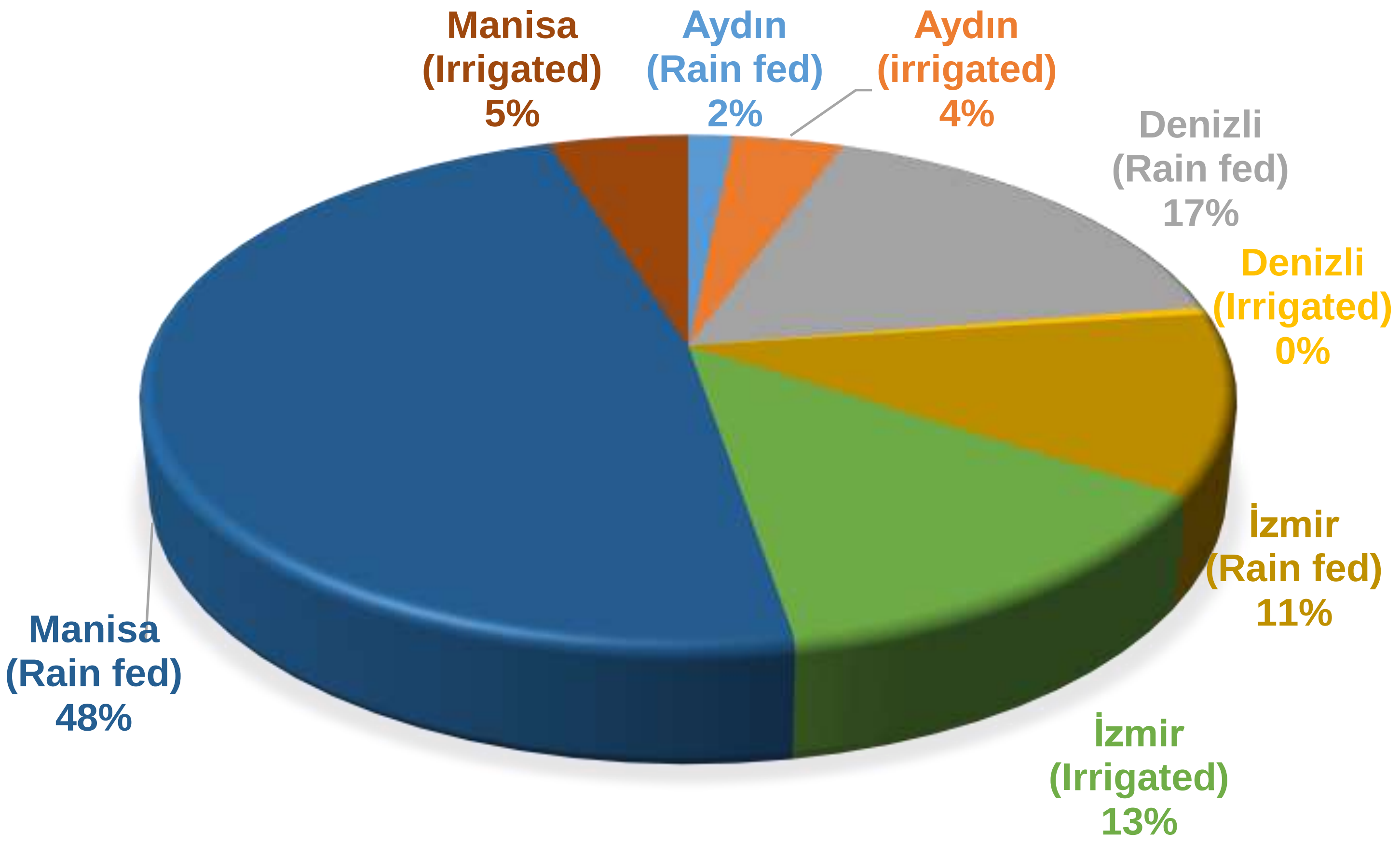
Field crop	Gasoline consumption (L/ha)
Barley	47.855
Dried beans	113.58
Table beans	38.055
Chick pea	82.55
Clover	43
Corn for silage	131
Corn	159.12
Cotton	222.03

CROP WATER REQUIREMENTS

Field crop	Seasonal water requirement (m^3/ha)	Irrigation requirement (m^3/ha)
Barley	4709.1	419.34*
Dried beans	4790	3634.8
Table beans	4790	3634.8
Chick pea	4680.9	3752.3
Clover	10143.8	7293.1
Corn for silage	2530	1794.9

Source: Canli ,2014 – calculations based on Penman-Monteith (FAO) procedure

CROP WATER REQUIREMENT ADJUSTMENTS



FERTILIZER RATES (kg/ha)

	Nitrate (kg/ha)	Phosphate (kg/ha)	Potassium (kg/ha)
Barley	90	40	0
Beans (Dried)	252.7	69.4	43.8
Beans for table	90	125	150
Chick pea	40	40	0
Clover	132.1	75	75
Corn	272.7	166.6	0
Corn for silage	272.7	166.6	0
Cotton	185.4	125	0

FINANCIAL VALUE (TL/ton – TIE 2014)

Field Crop	Domestic Financial Value (TL/ton)
Barley	620
Beans (Dried)	3690
Beans for table	1920
Chick pea	2330
Clover	520
Corn	620
Corn for silage	280
Cotton	1470

ENERGY AND CARBON EMISSION DATA

Energy need (kJ/kg)		
Nitrogen	Phosporus	Potassium
78230	17500	13800

Energy need for water (kWh/m^3)	
Groundwater	0.4068
Surface water by GDSHW	0.209
Groundwater by Solar Energy Solar	0.406

Carbon emissions of different sources	
Diesel gasoline*	0.002357 tons CO_2/L or 778 g CO_2/kWh
N, P and K fertilizers**	0.0026 tons/ kg
Hydroelectric power***	24 g CO_2/kWh
Solar panel toproof***	32 CO_2/kWh

SCENARIOS

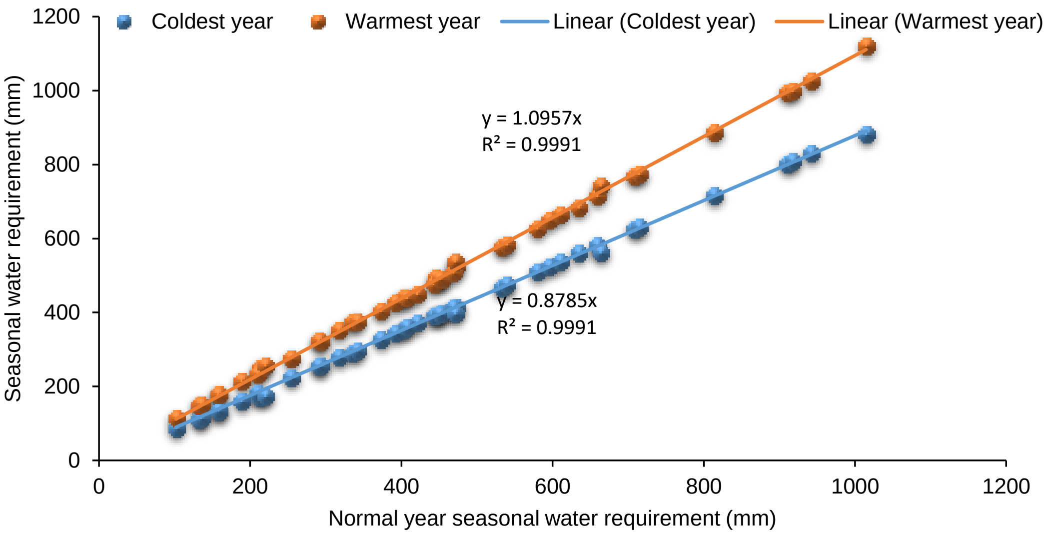
Near Future Scenarios

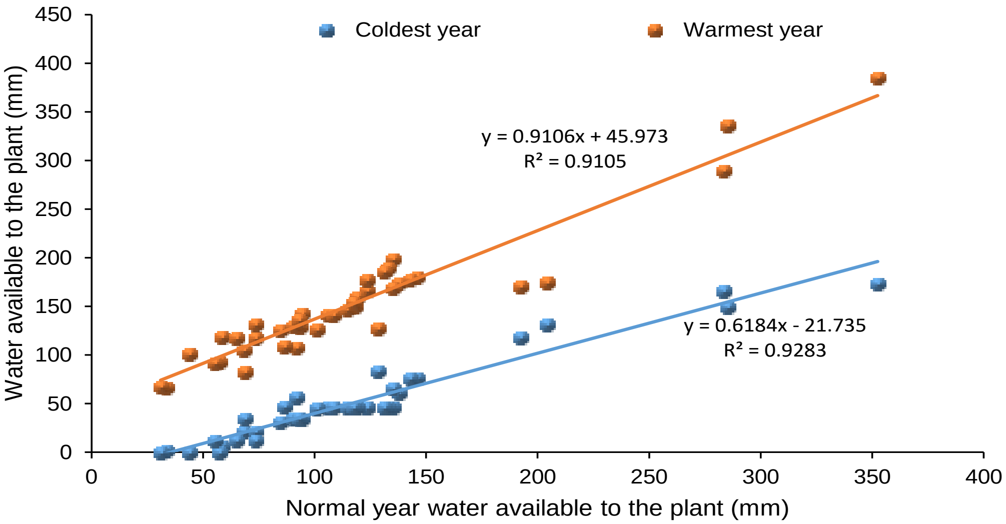
Long Term Scenarios

WHAT TO CONSIDER IN THE NEAR FUTURE SCENARIOS

Both, climate change and solar energy use were considered in the near future scenarios.

CLIMATE CHANGE CONSIDERATIONS IN THE NEAR FUTURE SCENARIOS





NEAR FUTURE SCENARIOS

5% of the total water used for irrigation was assumed to be pumps that use solar energy

SOLAR ENERGY CONSIDERATIONS IN THE NEAR FUTURE SCENARIOS

NFNSSE0 → Normal season and no solar energy used

NFNSSE05 → Normal season with %5 solar energy use

NFHSSE0 → Hot season and no solar energy used

NFHSSE05 → Hot season with %5 solar energy use

NFCSSE0 → Cold season and no solar energy used

NFCSSE05 → Cold season with %5 solar energy use

OUTPUT FOR THE YEAR 2014 - NFNSSE0 (top 15 crops)

Normal season and no solar energy used

W	Water (m^3)	1062105011.9
L	Land (ha)	529857.3

Water saving (m^3)	0
Land saving (ha)	0

E_1	E_{GWE} (kJ)	886595982226.5
	E_{GWS} (kJ)	0.0
	E_{GWG} (kJ)	343624958696.4
E_2	$E_{farming}$ (kJ)	2210083923902.4
	$E_{transport}$ (kJ)	170693673987.2
	$E_{fertilizer}$ (kJ)	6920075184949.7
F	F_{local} (TL)	6733675566.0
	F_{import} (TL)	0
C_1	C_{GWE} (tons)	5910.64
	C_{GWS} (tons)	0
	C_{GWG} (tons)	74261.2
C_2	$C_{farming}$ (tons)	143109.0
	$C_{transport}$ (tons)	11052.9
	$C_{fertilizer}$ (tons)	365676.9

E_1 (kJ)	1.23022E+12
E_2 (kJ)	9.30085E+12
$E = E_1 + E_2$ (kJ)	1.05311E+13
F (TL)	6733675566
C_1 (tons)	80171.8
C_2 (tons)	519838.7
$C = C_1 + C_2$ (tons)	600010.6

E_{imp} (kJ)	0
C_{imp} (tons)	0

OUTPUT FOR THE YEAR 2014 - NFNSSE0 (other 80 crops)

Normal season and no solar energy used

W	Water (m^3)	275473062.6	
L	Land (ha)	84059.9	

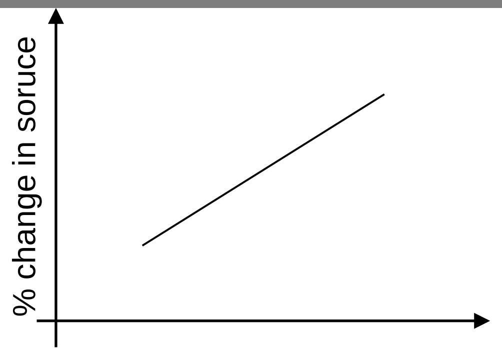
Water saving (m^3)			
Land saving (ha)			
E_{imp} (kJ)			
C_{imp} (tons)			

E_1	E_{GWE} (kJ)	229952130725.1
	E_{GWS} (kJ)	0.0
	E_{SWG} (kJ)	89124350895.6
E_2	$E_{farming}$ (kJ)	410533522326.2
	$E_{transport}$ (kJ)	32178345957.3
	$E_{fertilizer}$ (kJ)	1108624386374.1
F	F_{local} (TL)	2543810570.0
	F_{import} (TL)	0
C_1	C_{GWE} (tons)	1533.014205
	C_{GWS} (tons)	0
	C_{SWG} (tons)	19260.8
C_2	$C_{farming}$ (tons)	26583.2
	$C_{transport}$ (tons)	2083.6
	$C_{fertilizer}$ (tons)	67764.6

E_1 (kJ)	E_2 (kJ)	$E = E_1 + E_2$ (kJ)	F (TL)	C_1 (tons)	C_2 (tons)	$C = C_1 + C_2$ (tons)
3.19076E+11	1.55134E+12	1.87041E+12	2543810570	20793.8	96431.4	117225.2

SENSITIVITY RATIO

$$S_r = \left(\frac{O - O_b}{P_{b\pm\Delta} - P_b} \right) \frac{P_b}{O_b}$$

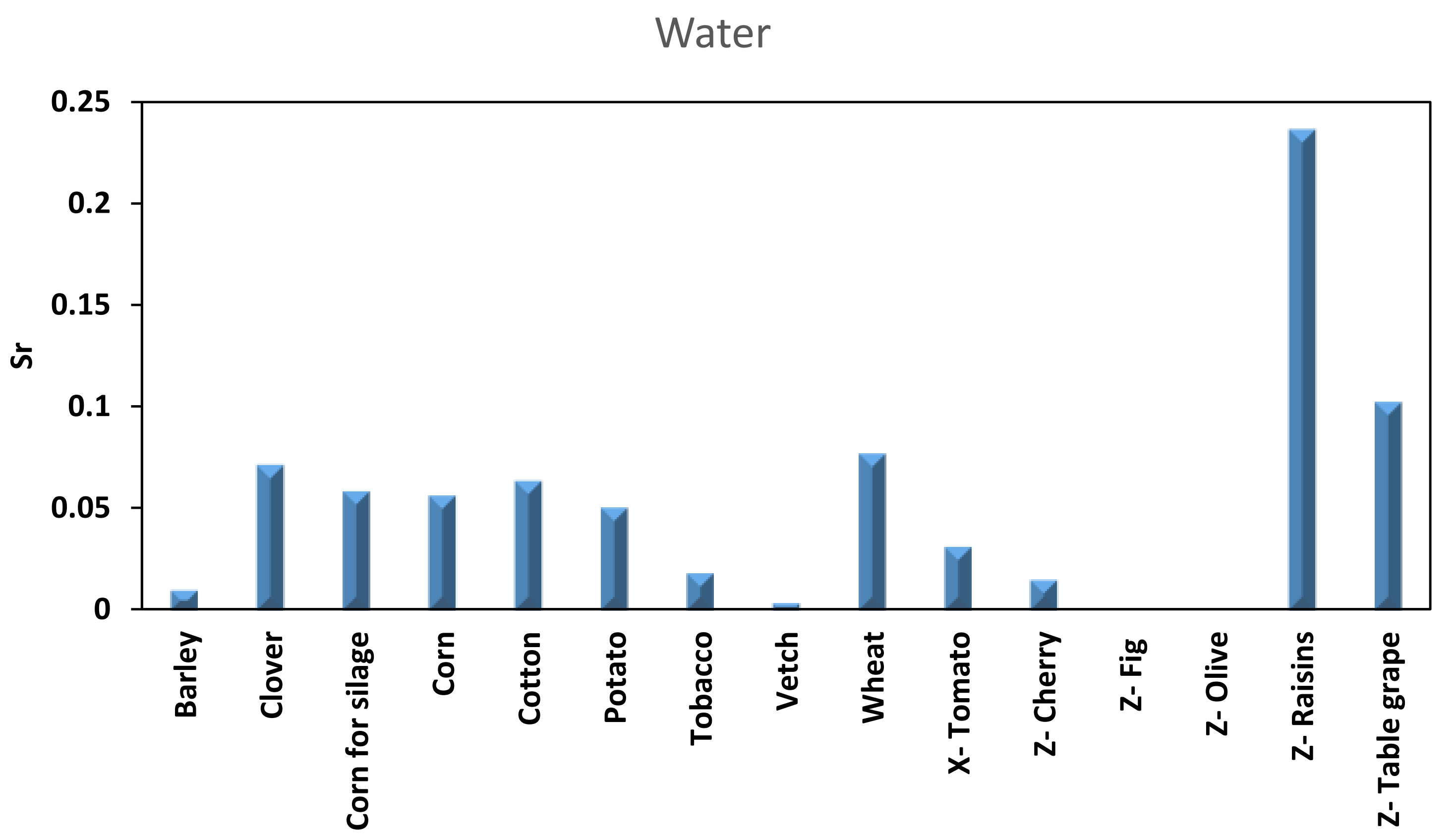


S_r is the relative sensitivity value, O is the new output, O_b is the output of base scenario, P is new parameter value, P_b is the base parameter value in base scenario. “b” is the base average value and Δ represents the change in parameter value from base

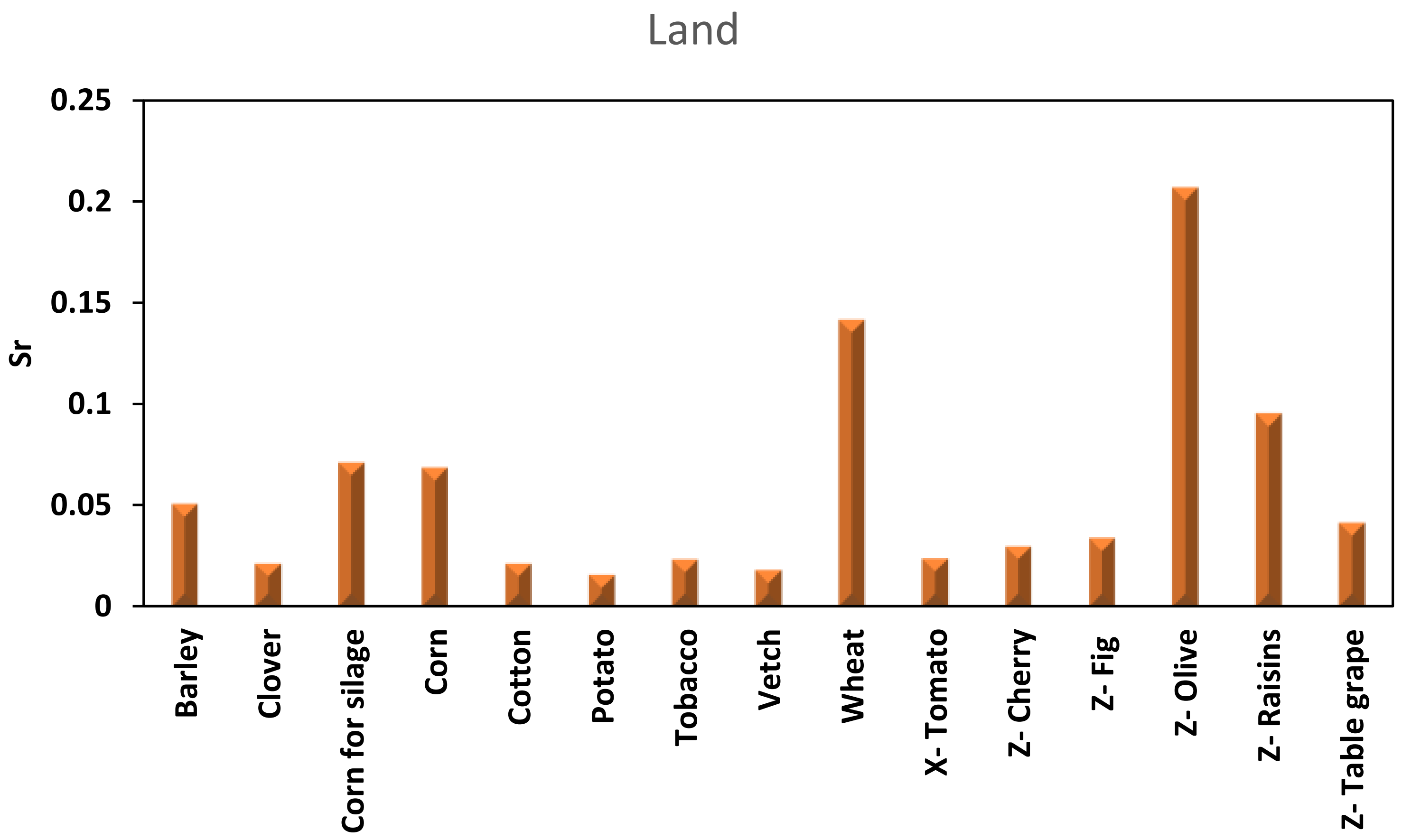
	O_b	O	$(O-O_b)$	$P_{(b\pm\Delta)}$	P_b	$P_{(b\pm\Delta)} - P_b$	P_b/O_b	S_r
W (m^3)	1337578074	1334973352	-2604722.023	0.8	1	-0.2	7.4762E-10	0.009737

Source: Daher, 2012

WATER SENSITIVITY RATIO



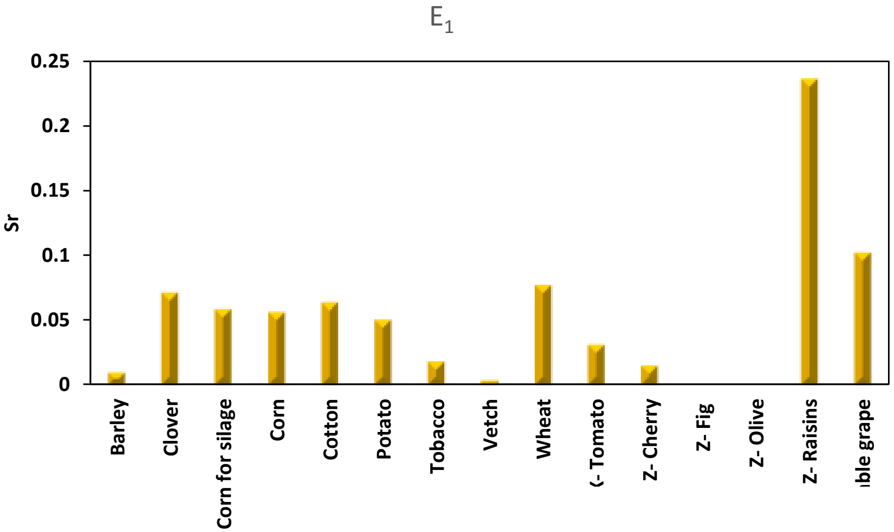
LAND SENSITIVITY RATIO

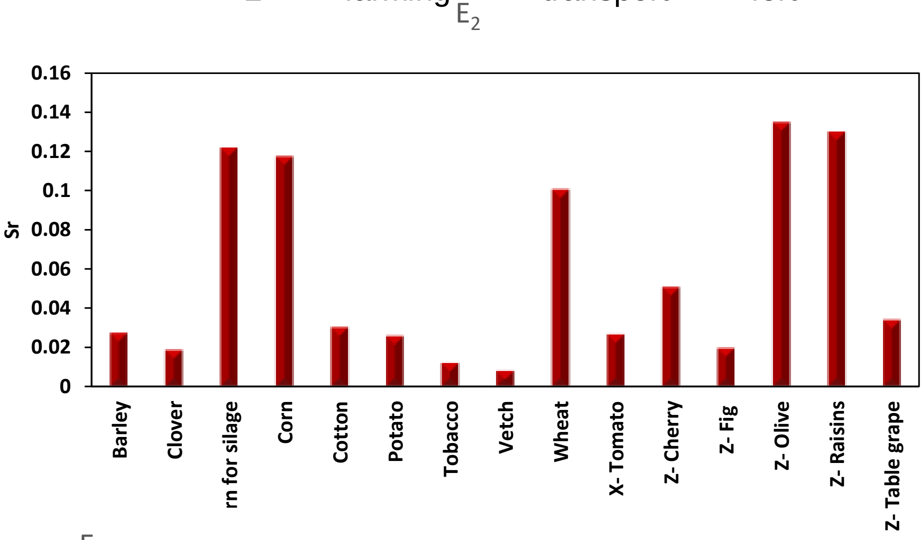


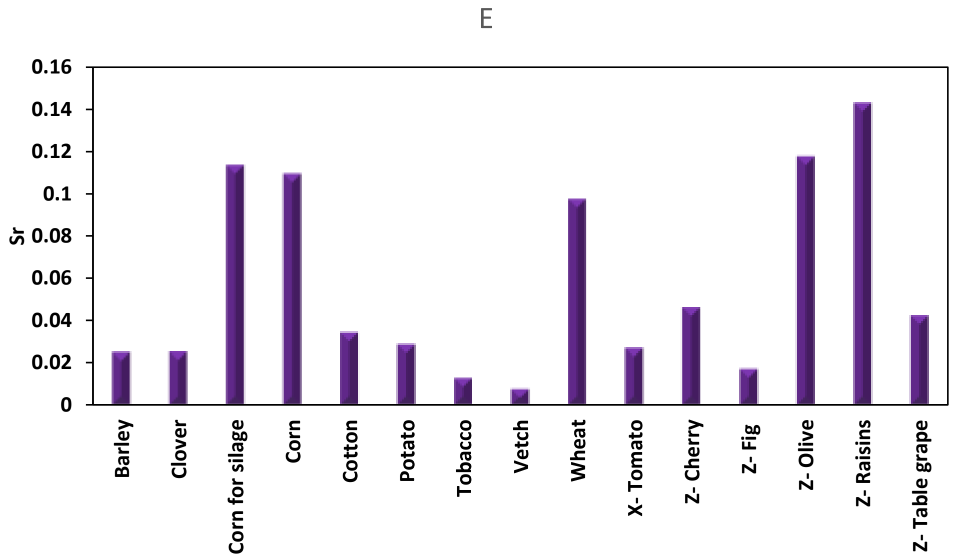
ENERGY SENSITIVITY RATIO

$$E_1 = E_{GWe} + E_{GWs} + E_{SW}$$

$$E_2 = E_{farming} + E_{transport} + E_{fert}$$

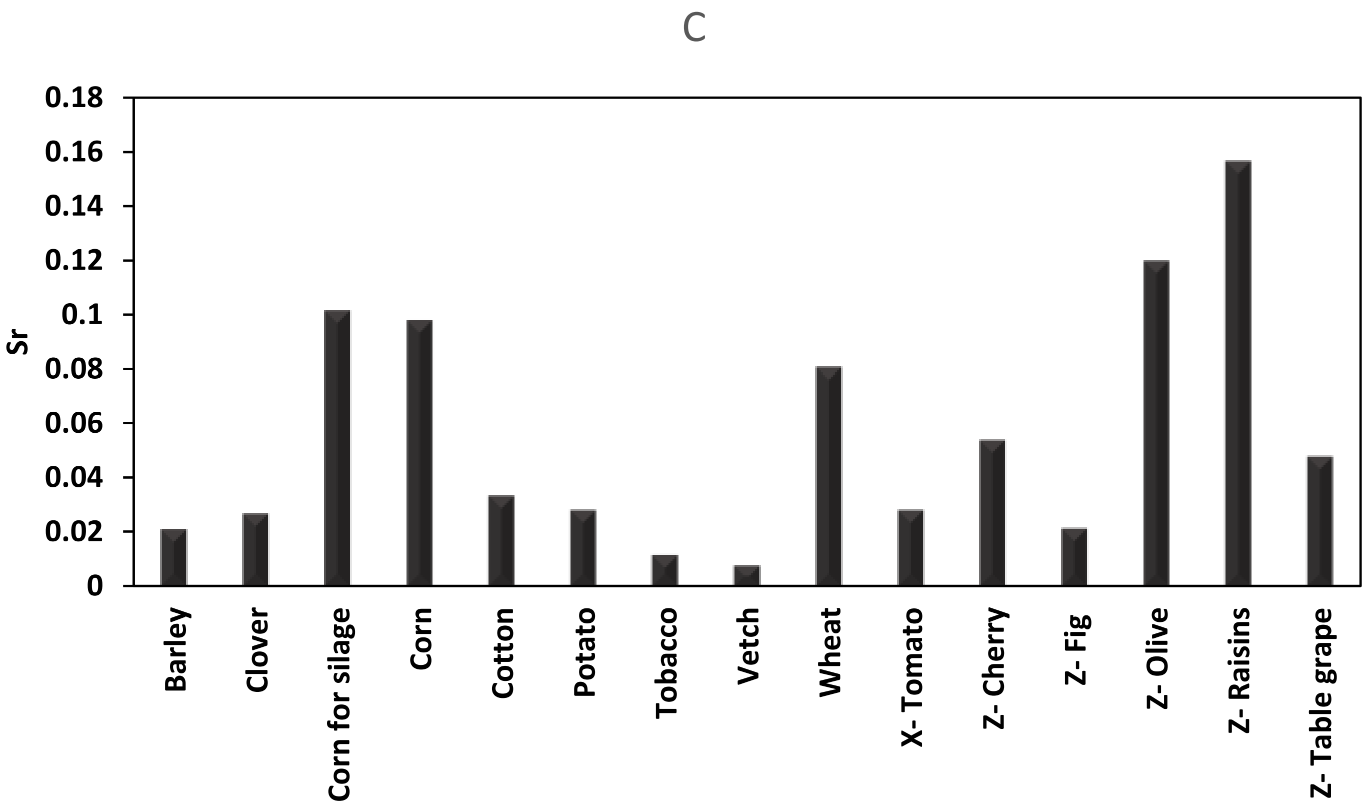




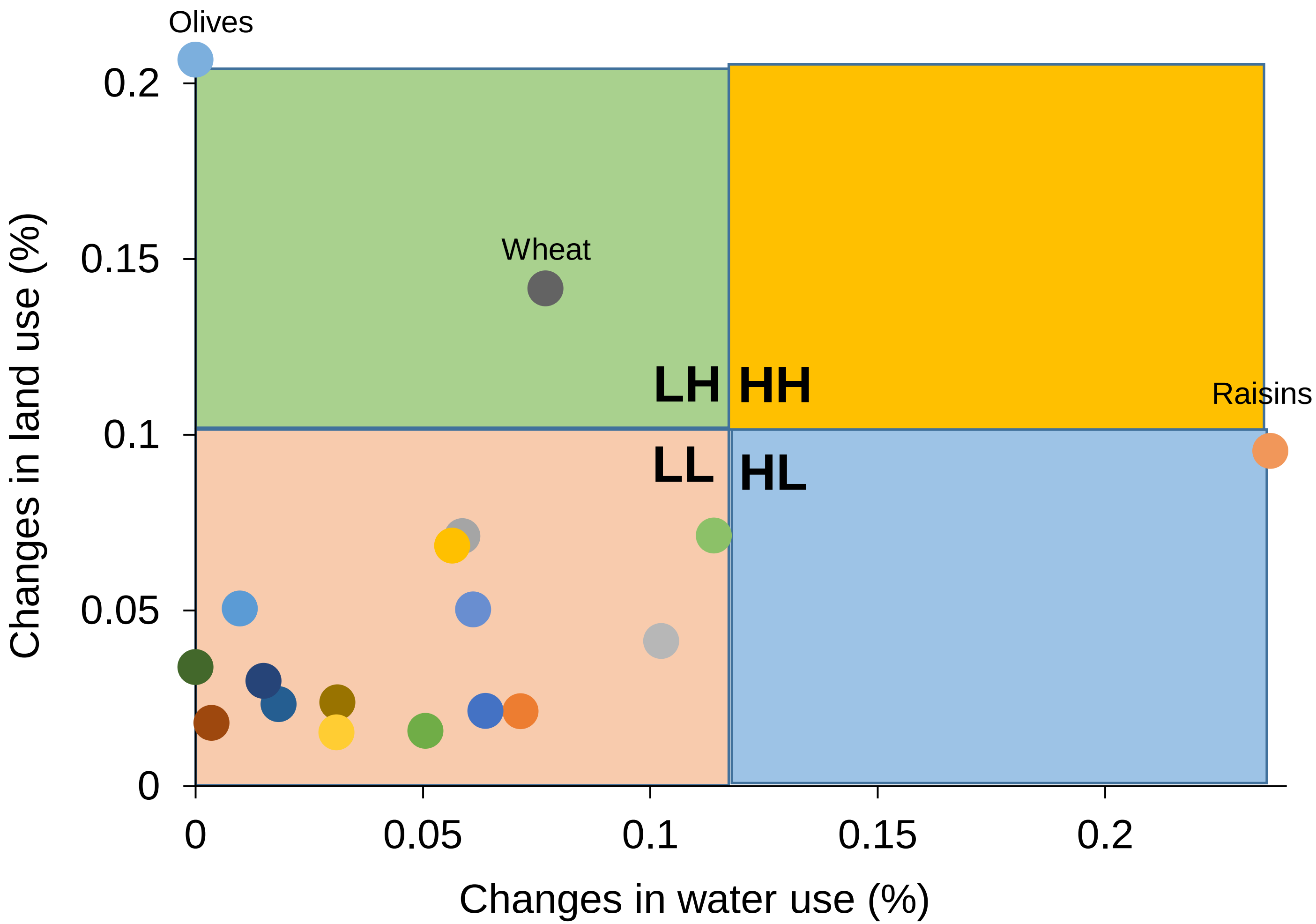


CARBON SENSITIVITY RATIO

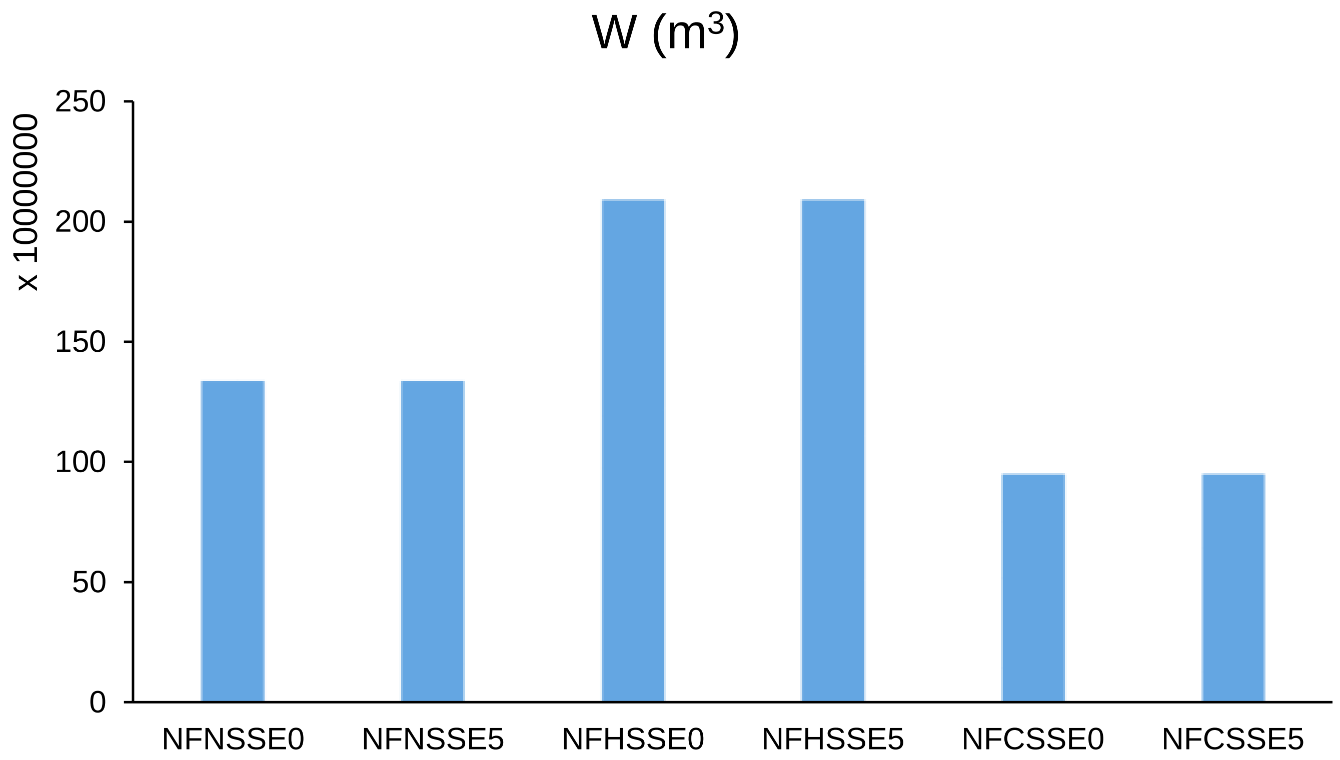
$$C = C_1 + C_2$$
$$C_1 = C_{GWe} + C_{GWs} + C_{SW}$$
$$C_2 = C_{farming} + C_{transport} + C_{fert}$$



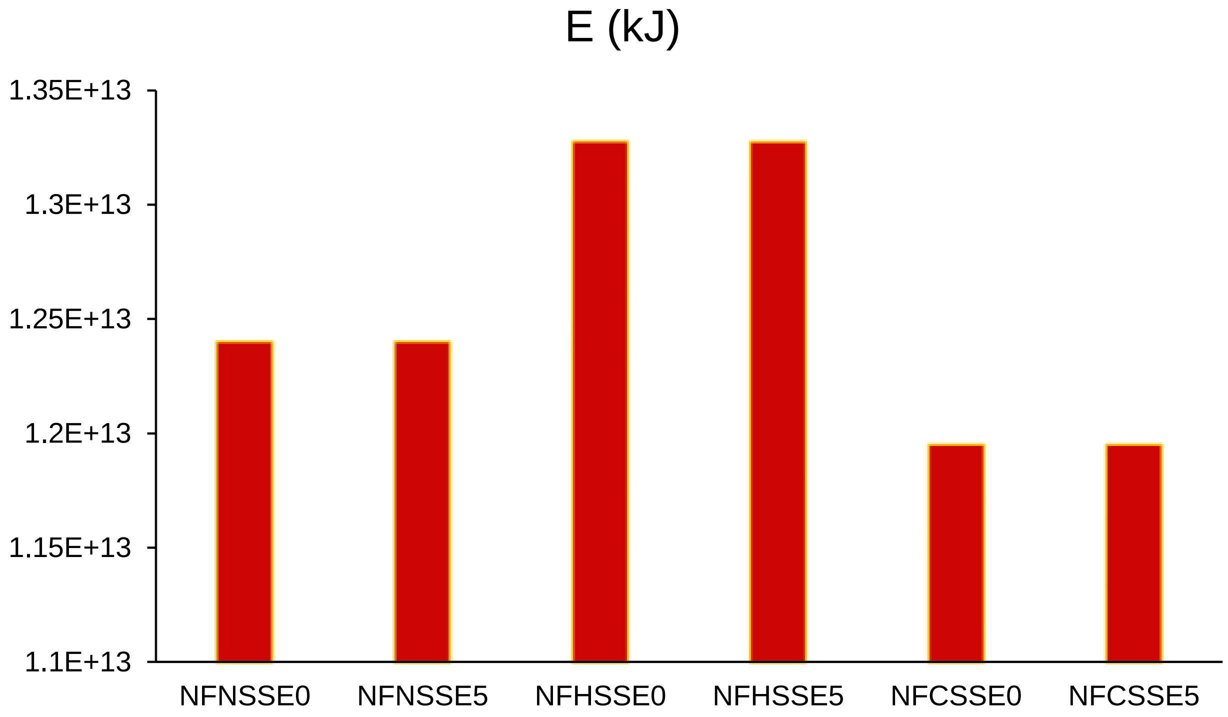
GROUPING CROPS BASED ON THE SENSITIVITY RATIOS



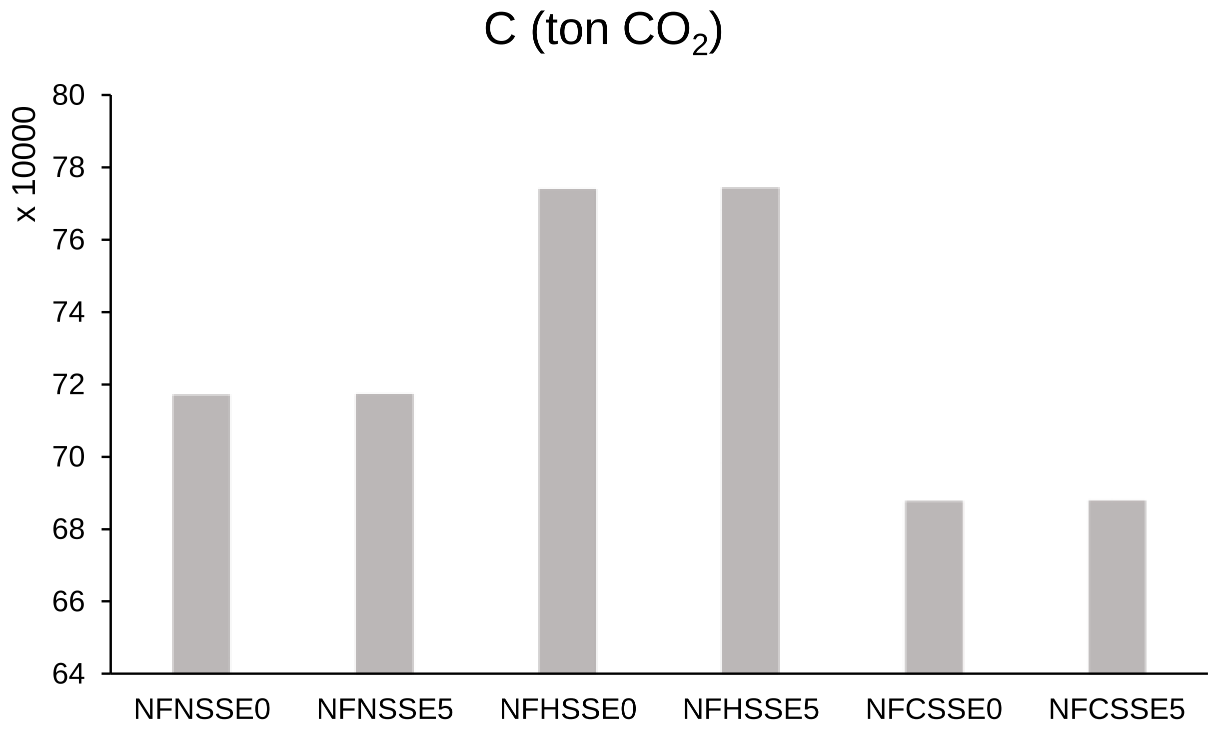
WATER REQUIREMENTS IN NEAR FUTURE SCENARIOS



ENERGY REQUIREMENTS IN NEAR FUTURE SCENARIOS



CARBON EMISSIONS IN NEAR FUTURE SCENARIOS



SUSTAINABILITY INDEX

$$S.I.\ i = [WI_i (100-I_W) + LI_i\ (100-I_L) + EI_i\ (100-I_E) + CI_i\ (100-I_C) + FI_i\ (100-I_F) + EIMP\ I_i\ (100-I_{EIMP}) + CIMP\ I_i\ (100-I_{CIMP})]\ /100$$

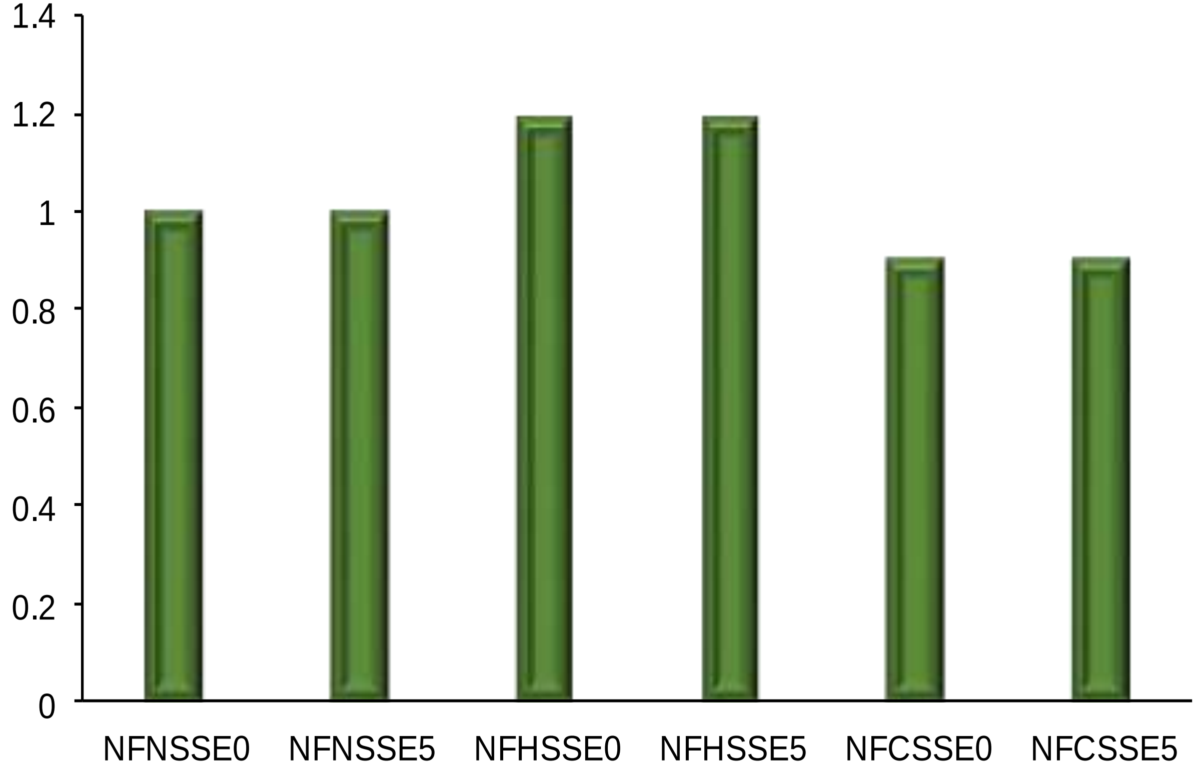
Wi = the total water needed for scenario i
Li = the total land area needed for scenario i
Ei = the total local energy needed for scenario i
Ci = the total local carbon emitted by scenario i
Fi = the total finances for scenario i

Wa = total max acceptable water extracted and produced by available water resources
La = max acceptable/arable local land use
Ea = max acceptable energy use
Ca = max acceptable carbon emissions
Fa = max acceptable limits for expenditures to supply food locally and through imports

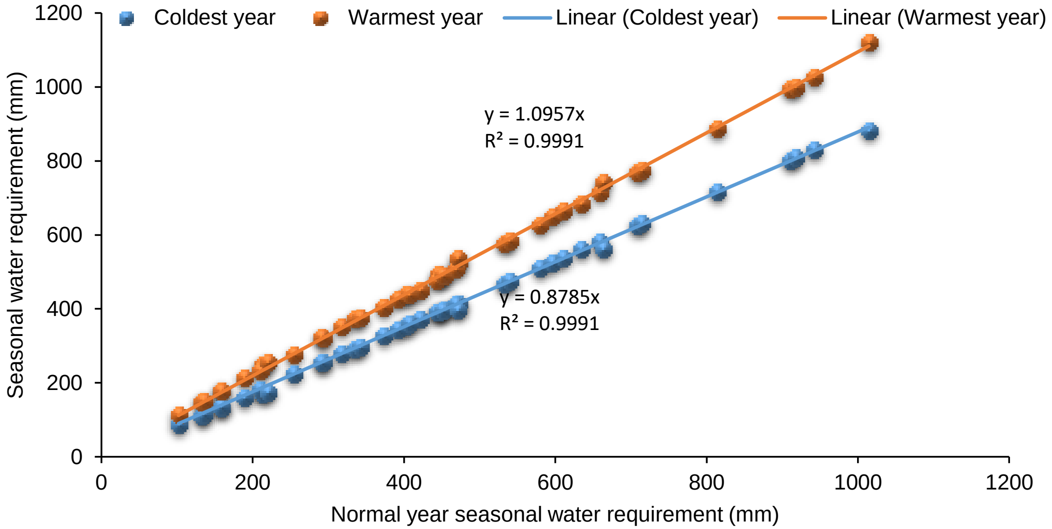
$$I_W + I_L + I_E + I_C + I_F + I_{EIMP} + I_{CIMP} = 100$$

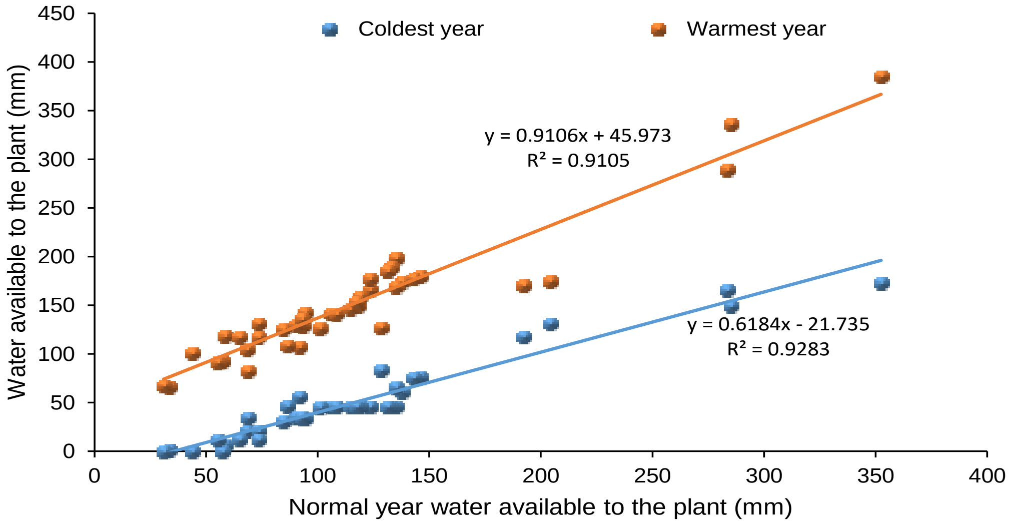
Assesement parameters

SUSTAINABILITY INDEX FOR NEAR FUTURE SCENARIOS

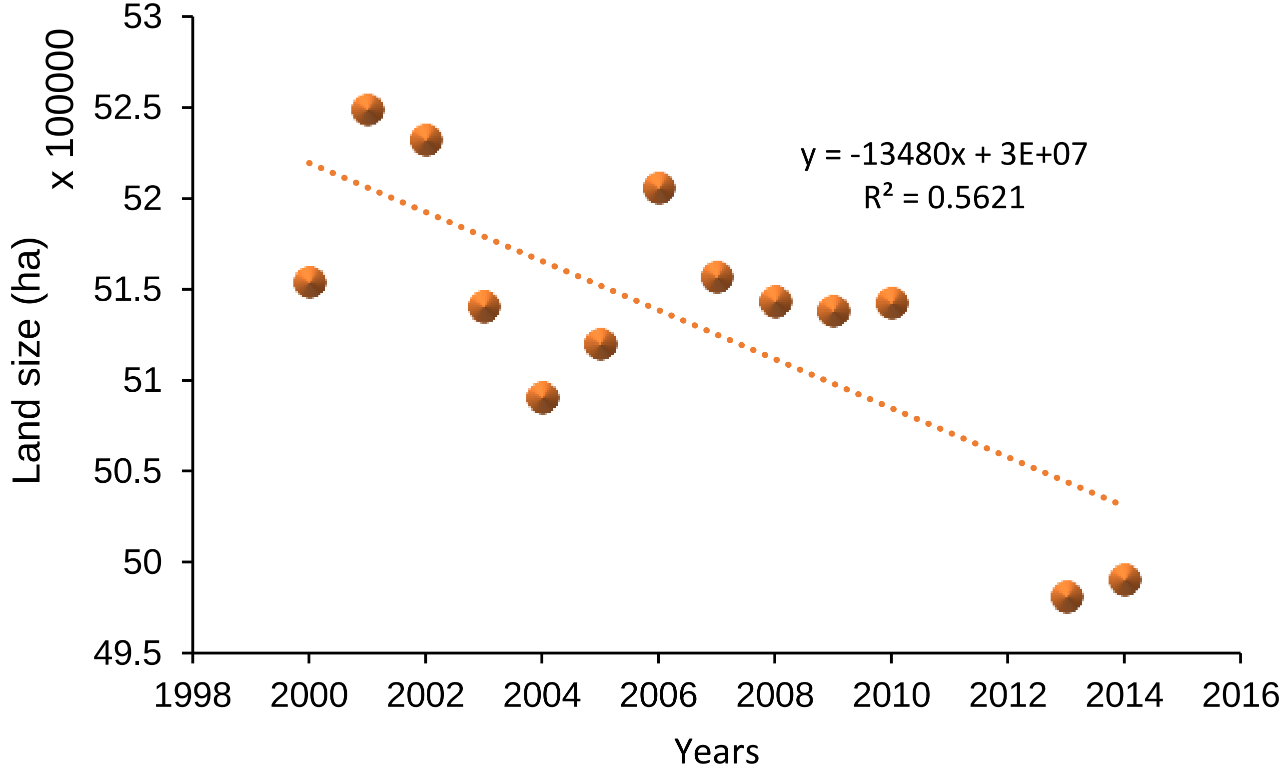


LONG TERM SCENARIOS (CLIMATE CHANGE)





URBANIZATION



CHANGES IN TECHNOLOGY AND SOURCES

Solar energy use for groundwater pumping was increased and assumed to be 5, 10 and 15 % of the total water need was pumped by solar energy use for the years 2030, 2040 and 2050, respectively

GENERAL DIRECTORATE OF STATE HYDRAULIC WORKS

Surface water use was increased from 43 to 53% in some of the long term scenarios since the General Directorate of State Hydraulic Works will be implementing some projects

LONG TERM SCENARIOS

As a result of urbanization, climate change, and considering changes in surface water use and solar energy use, 12 scenarios for each year (2030, 2040 and 2050) were developed in the study.

LONG TERM SCENARIOS – URBANIZATION

2030**U** → **U** refers to Urbanization and in this year land size was reduced by … %

2040**U** → land size was reduced by … %

2050**U** → land size was reduced by … %

LONG TERM SCENARIOS – CLIMATE CHANGE

2030U**NS** → **NS** stands for normal season climate with precipitation

2030U**HS** → **HS** stands for hot season with less precipitation

2030U**CS** → **CS** means cold season with below average temperature and more precipitation

LONG TERM SCENARIOS – SOLAR ENERGY

2030UNS**SE0** → Normal season and no solar energy used

2030UNS**SE5** → Normal season with %5 solar energy use

2040UNS**SE0** → Normal season and no solar energy used

2040UNS**SE10** → Normal season with %10 solar energy use

2050UNS**SE0** → Normal season and no solar energy used

2050UNS**SE15** → Normal season with %15 solar energy use

LONG TERM SCENARIOS – CHANGES IN SOURCE OF WATER

2030UCSSW53SE0

2030UCSSW53SE5

2030UHSSW53SE0

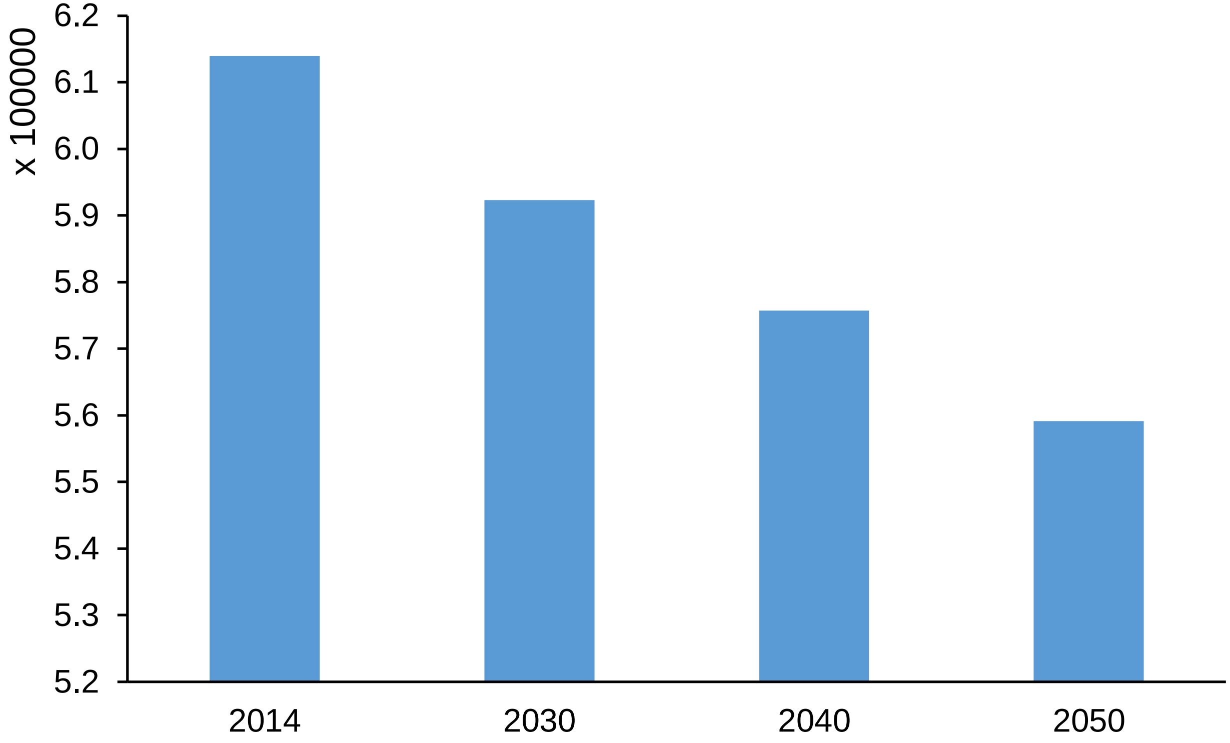
2030UHSSW53SE5

2030UNSSW53SE0

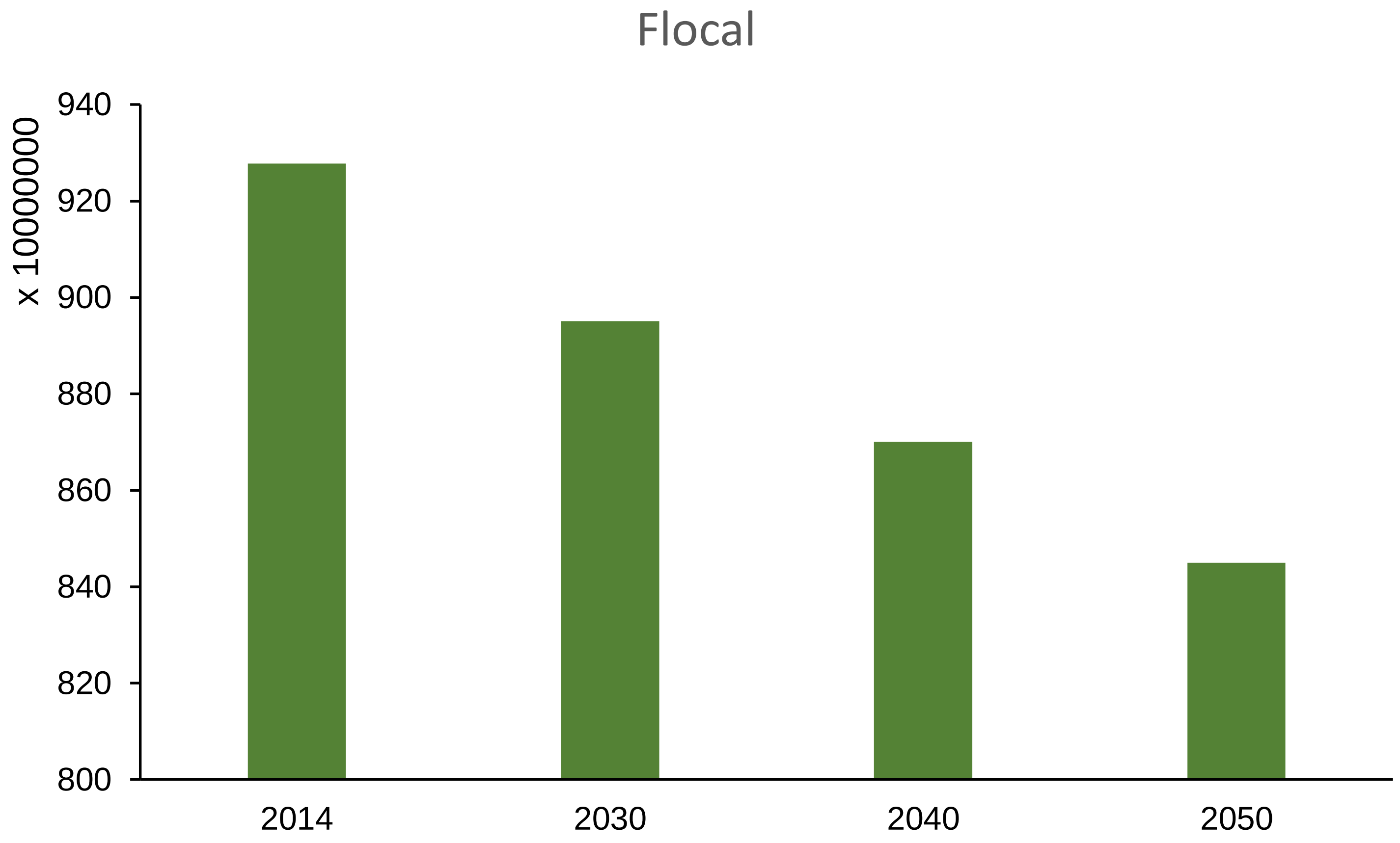
2030UNSSW53SE5

Normal, Cold and hot season with increased surface water use (from 43 to 53%) and with/without solar energy of 5%)

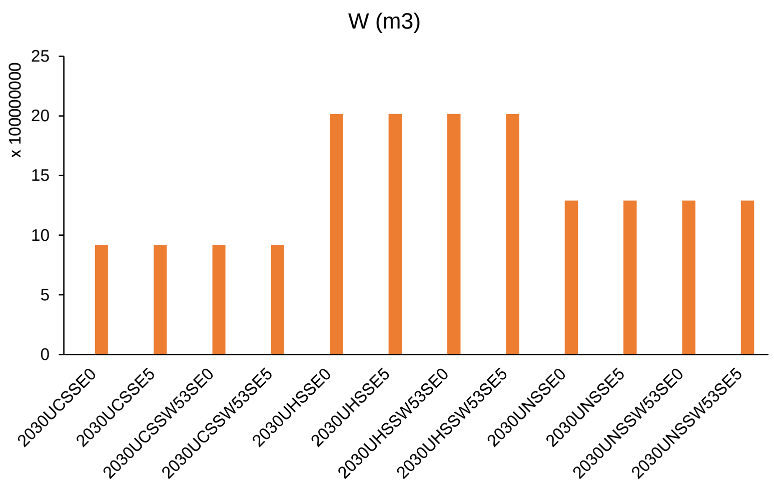
LAND REDUCTION DUE TO URBANIZATION

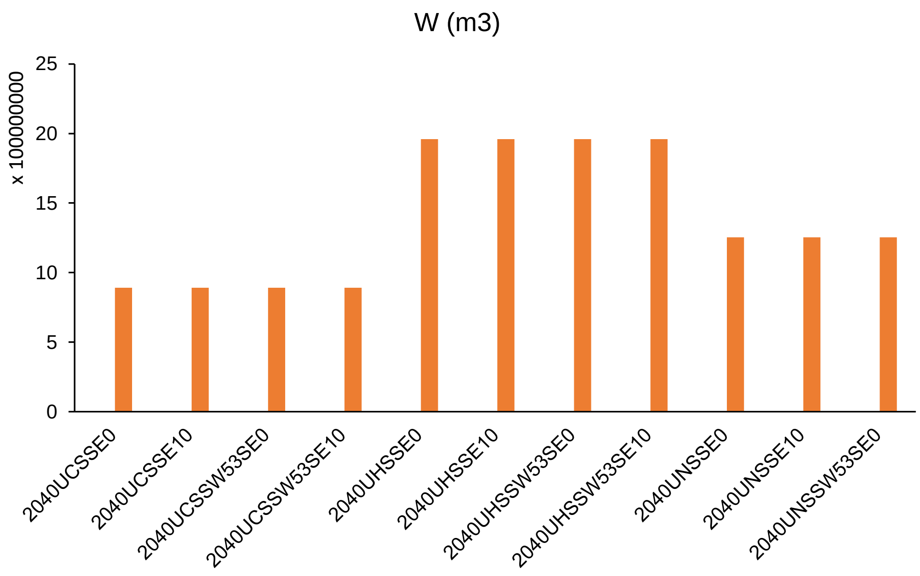


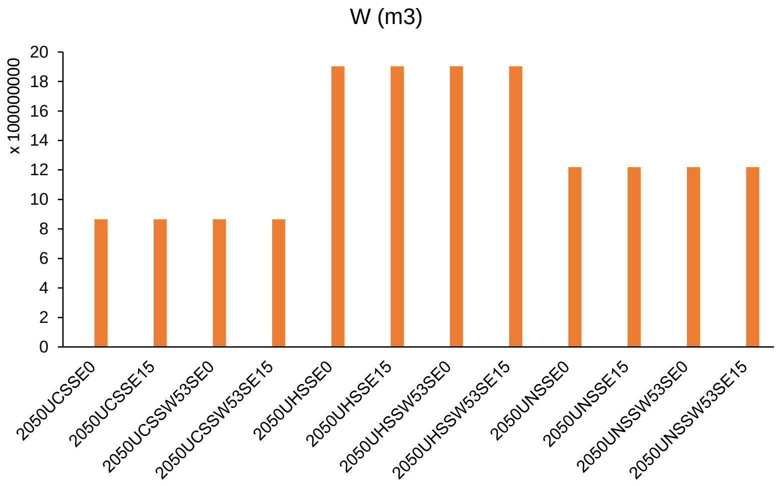
CHANGES IN LOCAL COSTS IN LONG TERM SCENARIOS



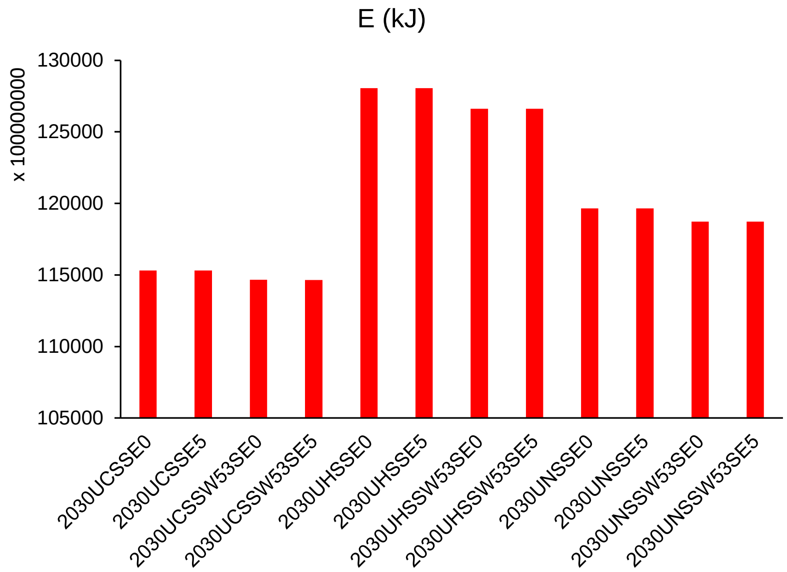
WATER REQUIREMENTS IN LONG TERM SCENARIOS

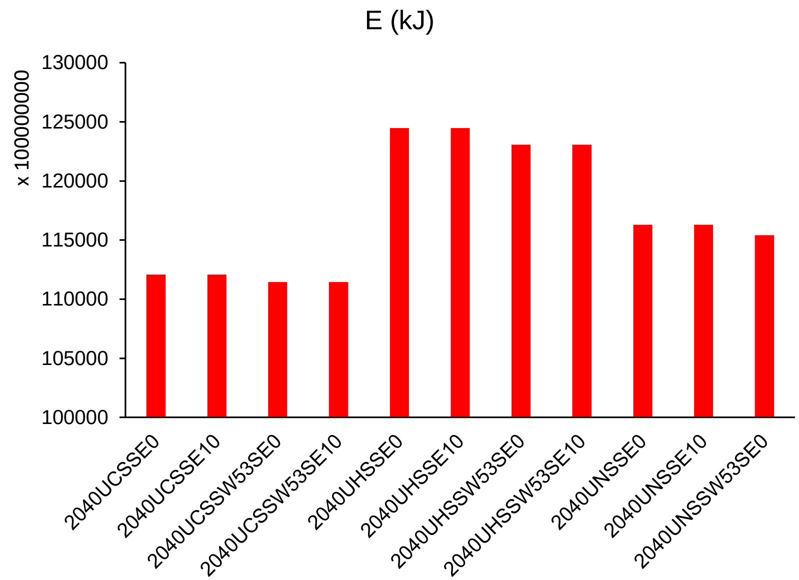


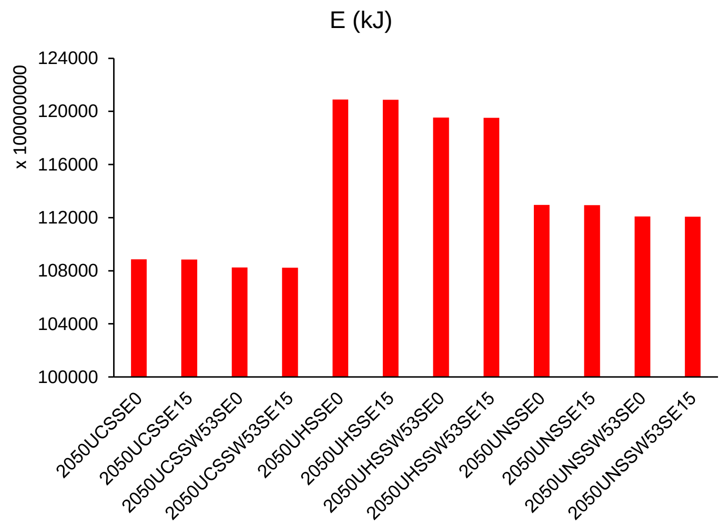




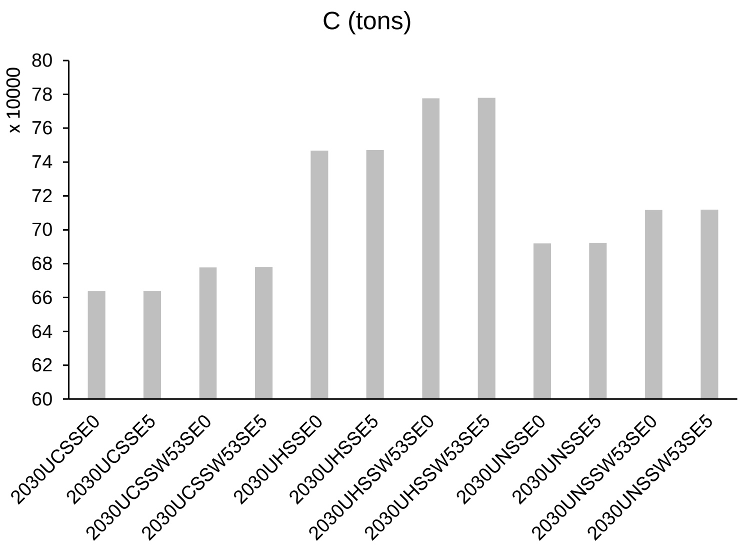
ENERGY NEEDS IN LONG TERM SCENARIOS

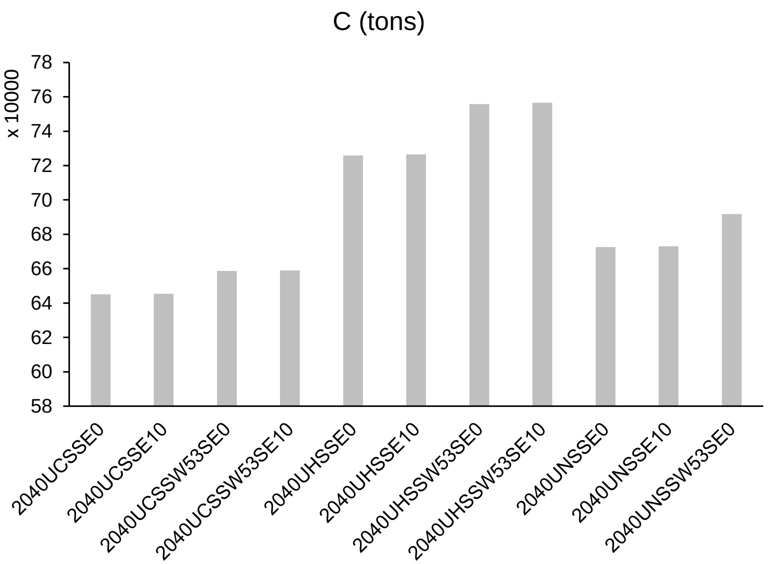


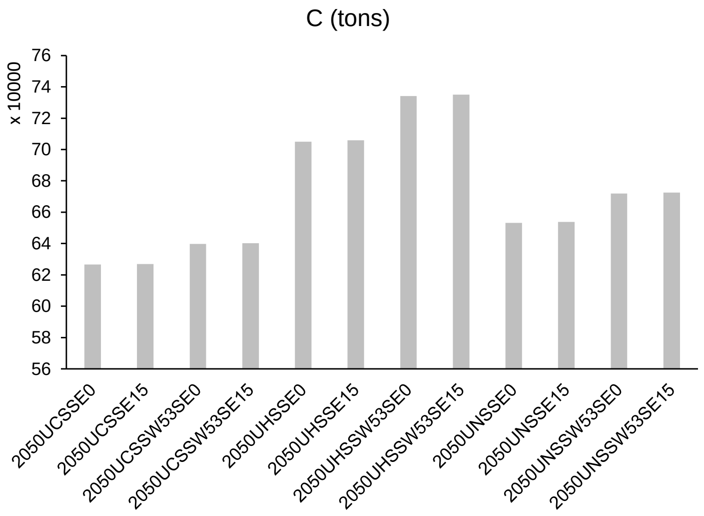




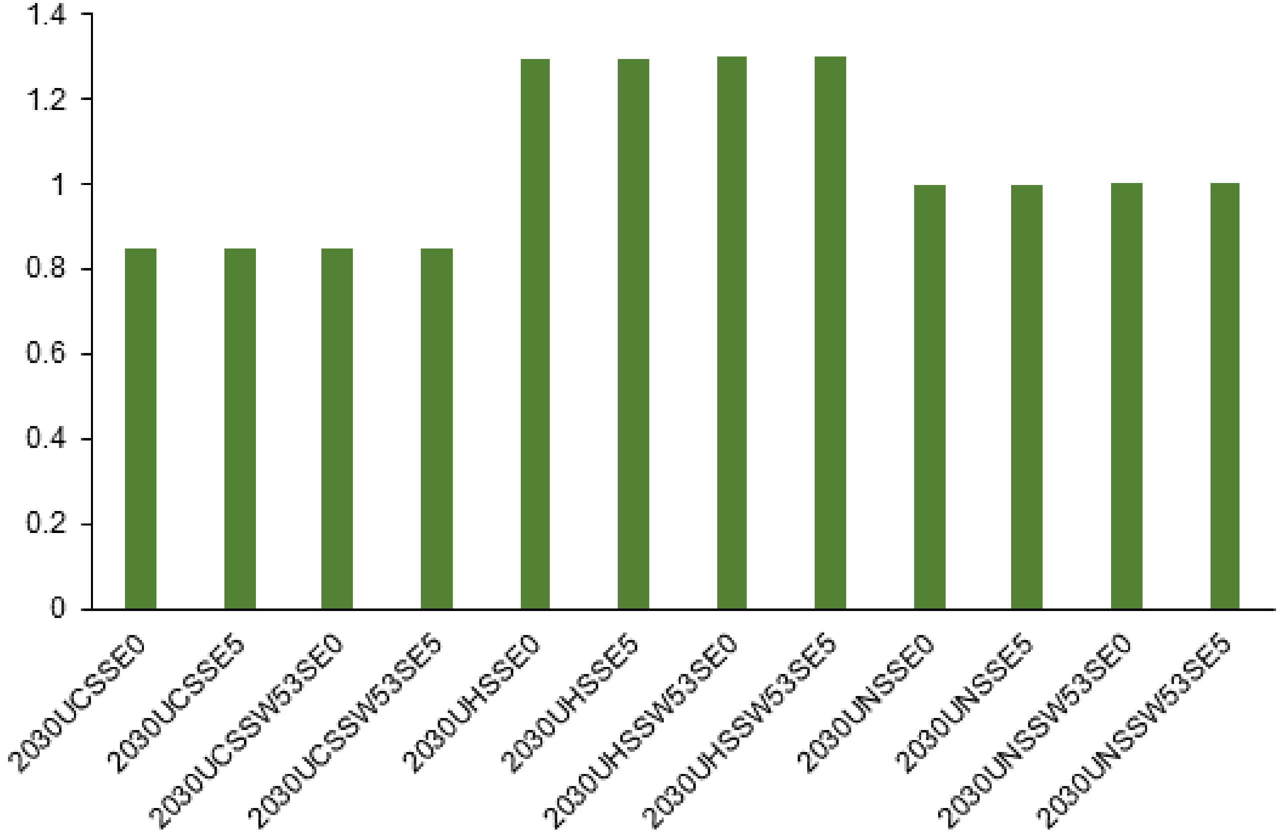
CARBON EMISSIONS IN LONG TERM SCENARIOS



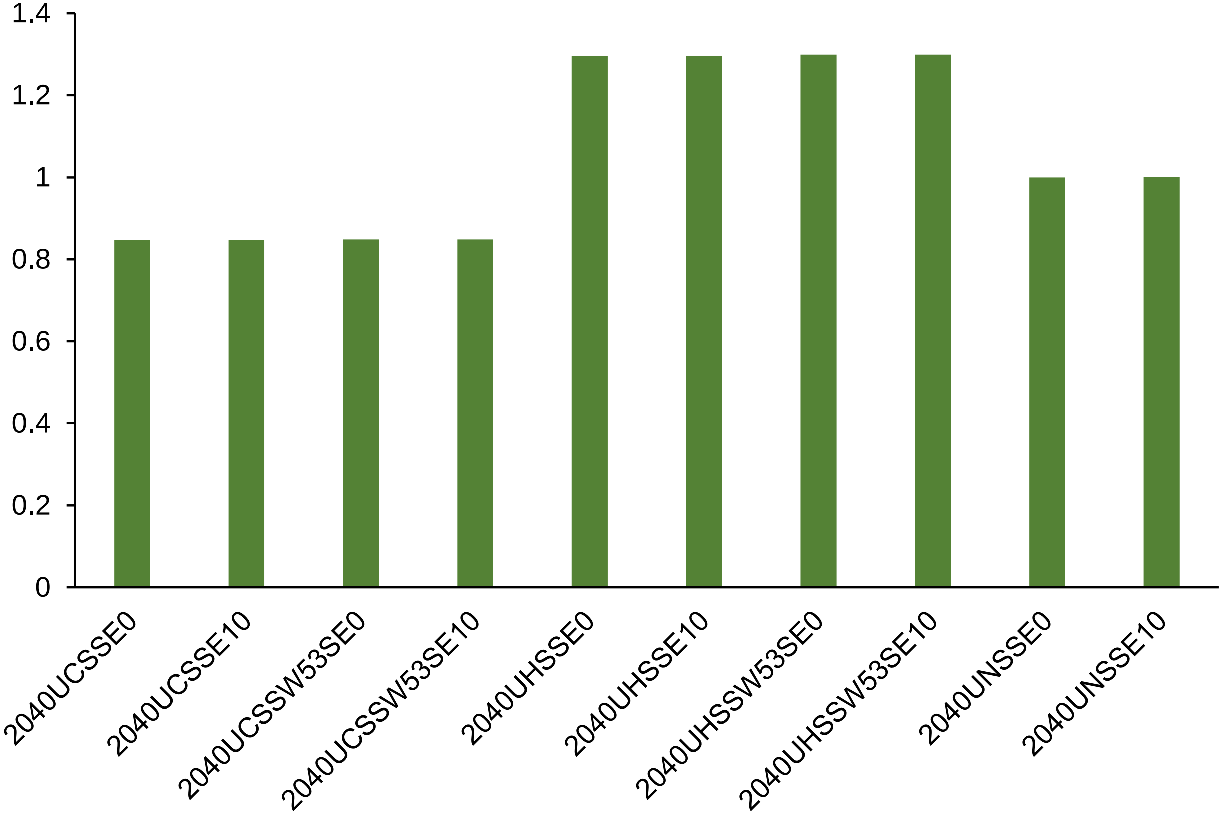




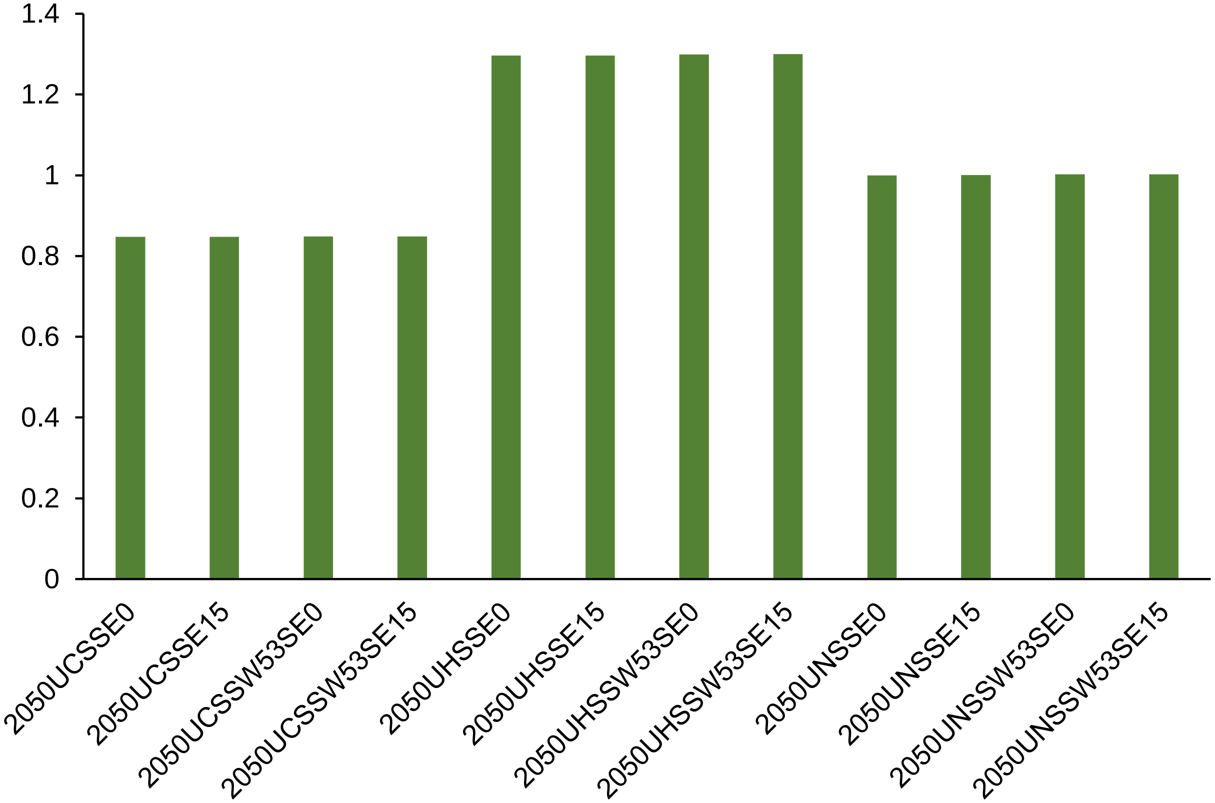
SUSTAINABILITY INDEX IN LONG TERM SCENARIOS



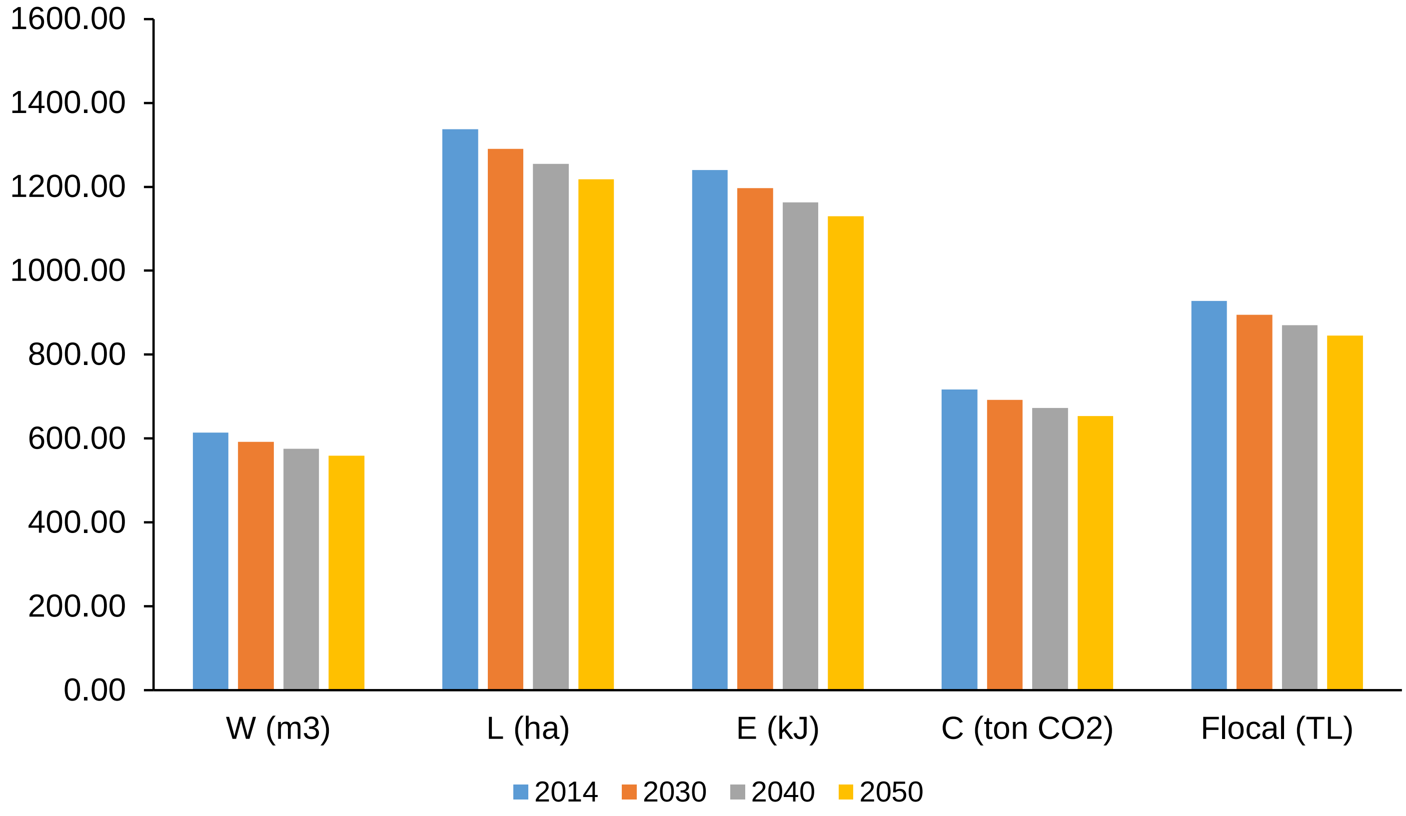
SUSTAINABILITY INDEX IN LONG TERM SCENARIOS



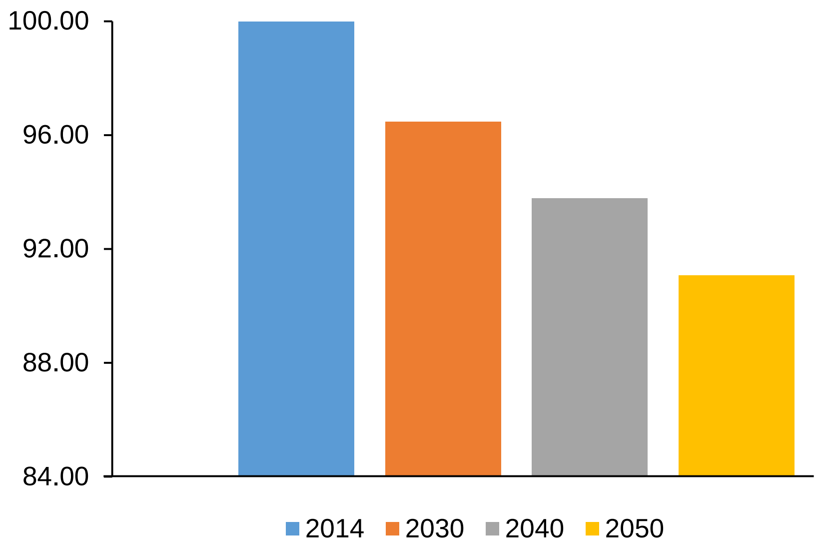
SUSTAINABILITY INDEX IN LONG TERM SCENARIOS

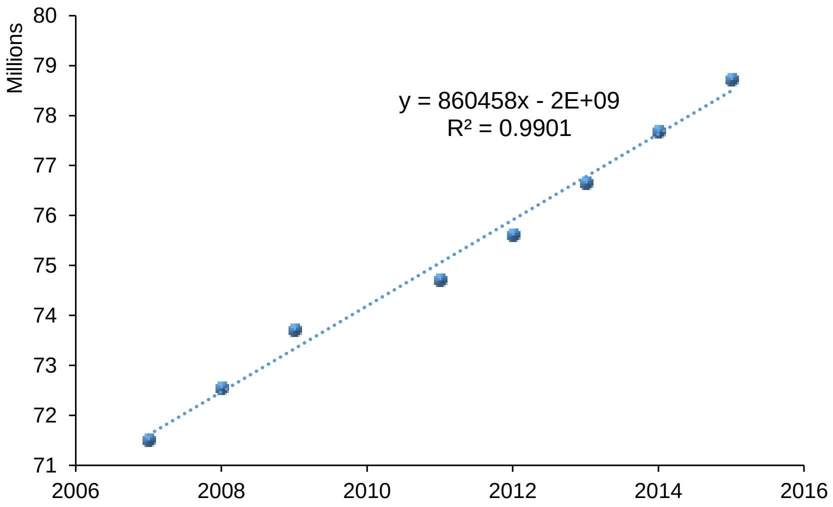


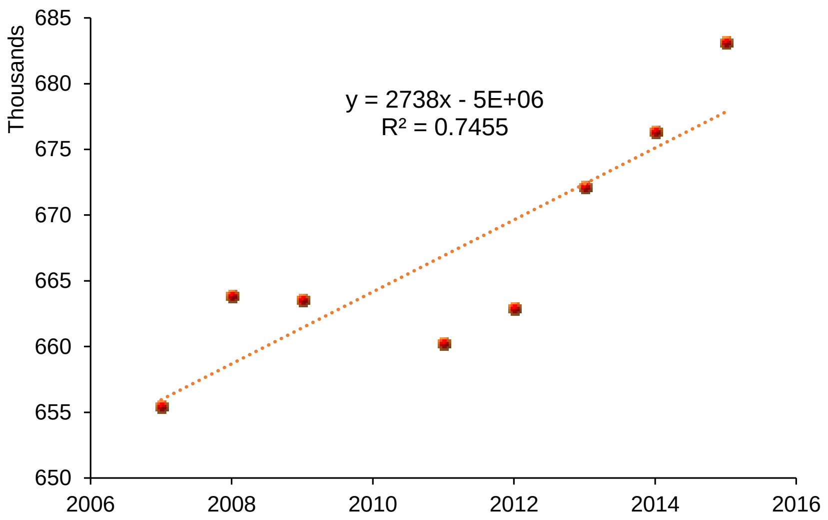
TRADEOFFS


1600.00
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
W (m3)
L (ha)
E (kJ)
C (ton CO2)
Flocal (TL)
2014
2030
2040
2050

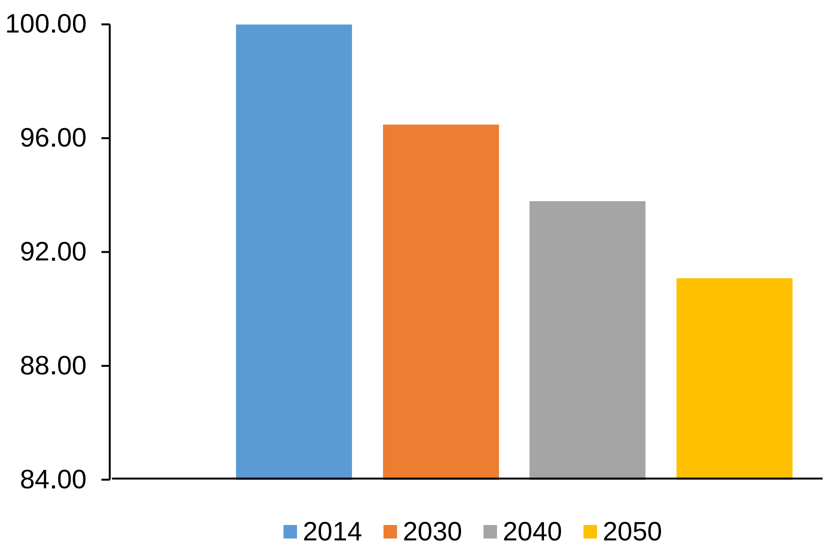
TRADEOFFS – REDUCTION IN SELF SUFFICIENCY vs POPULATION GROWTH

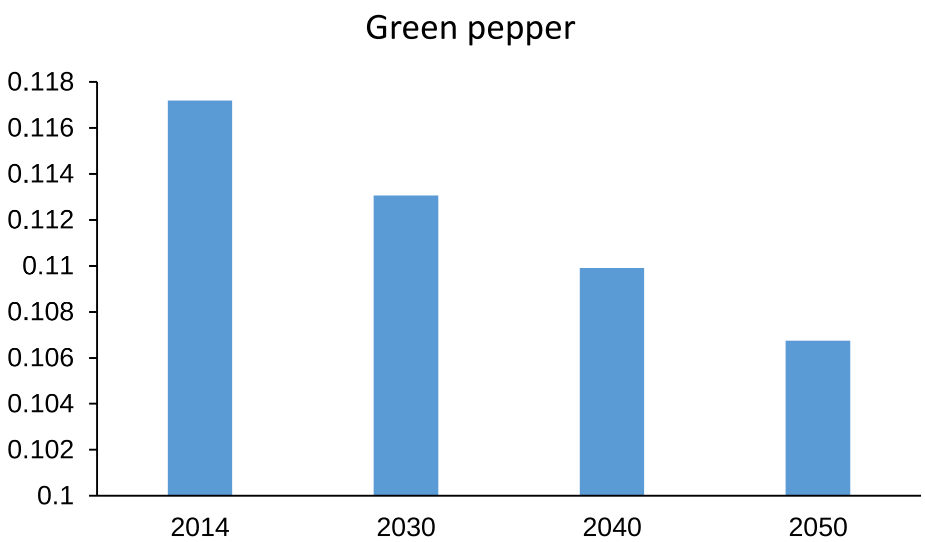


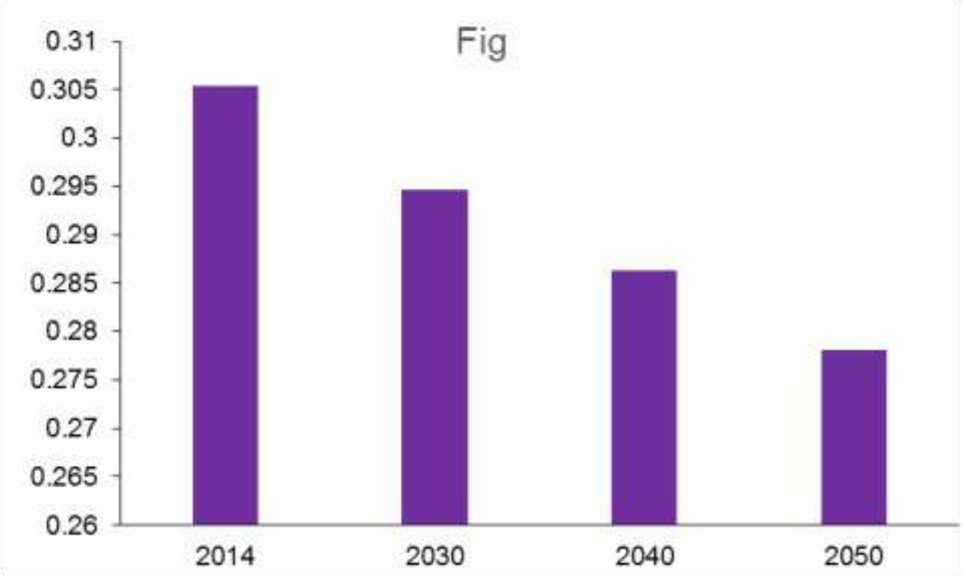




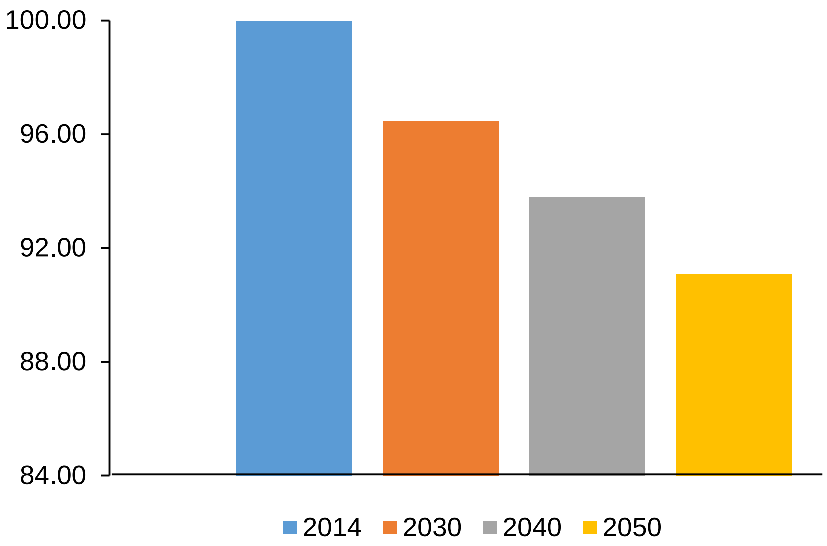
TRADEOFFS – REDUCTION IN PRODUCTION vs EXPORT

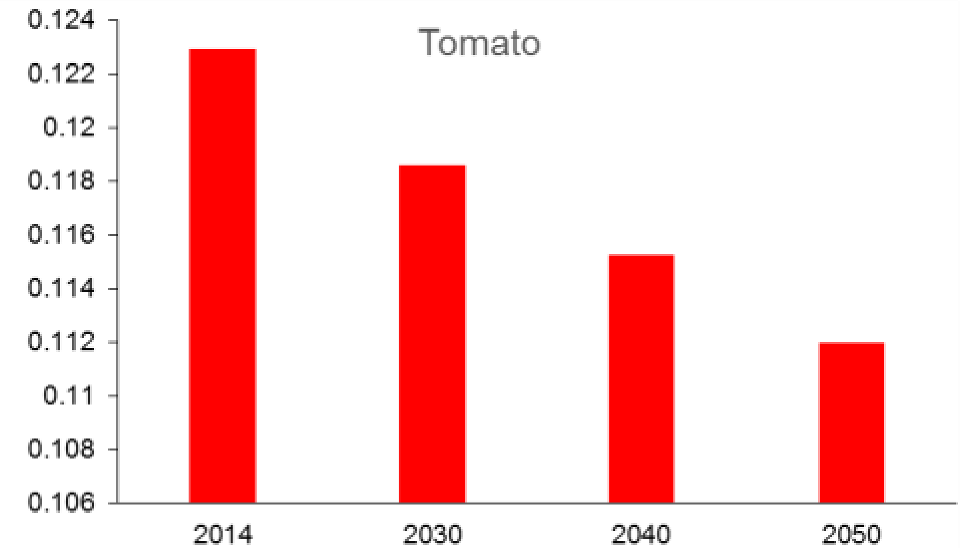


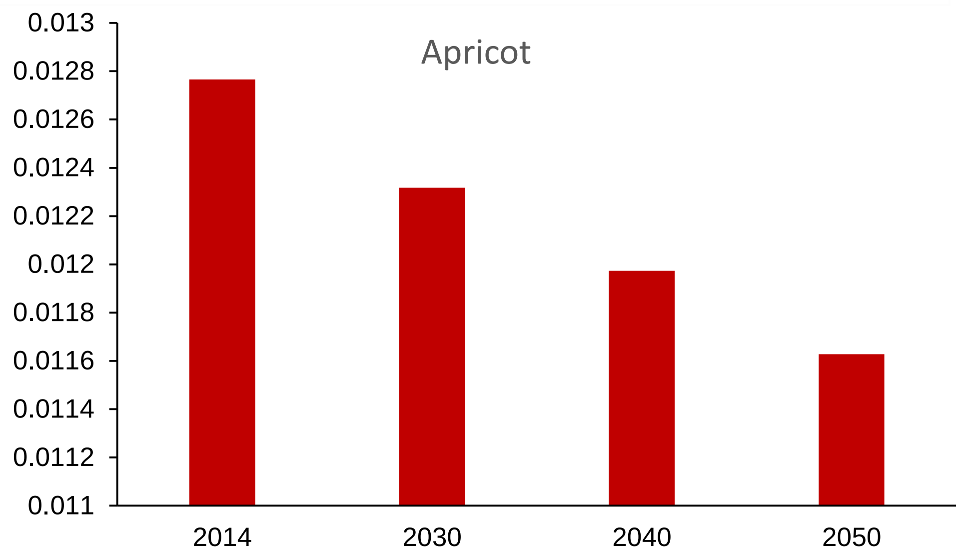




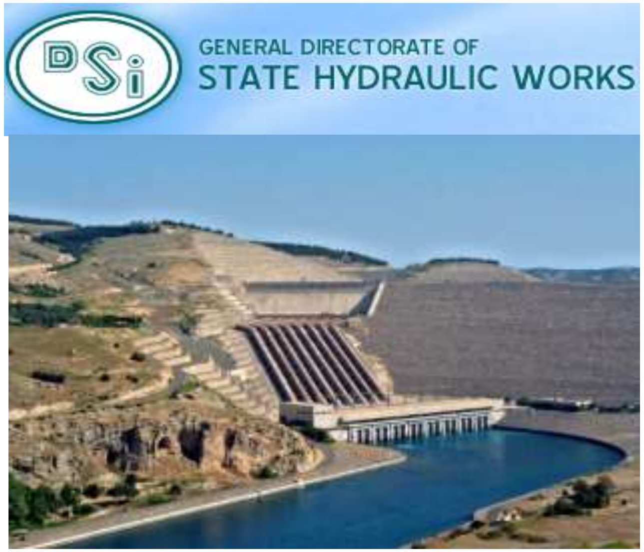
TRADEOFFS – REDUCTION IN PRODUCTION vs EXPORT







TRADEOFFS – SURFACE WATER USE AND GROUNDWATER LEVEL



Increase in surface water use from 43 to 53% and cold season may help the recovery of groundwater depth

CONCLUSIONS

- The crop pattern in the region is an effective parameter for land allocation and water demand and olive, wheat and raisin production are considered to be the governing crops in the basin in this respect. Changes in the crops pattern in the future may cause a shift toward more water need and/or land allocation. Hence, the management in the basin requires to create linkages between natural sources.
- It may be concluded that the self sufficiency and sustainability in the basin will worsen in the long term as compared to the year 2014.
- The reduction in land as a consequence of urbanization and water scarcity due to climate change are inevitable but in order to keep the sustainability at the same level, varieties that are resistant to drought should be selected while some new farming practices such as direct planting and employing drip irrigation systems in the production should be considered seriously.

CONCLUSIONS

- Environment friendly applications in agriculture are believed not only reduce energy inputs but also will help the sources to be less polluted. These applications could be stated as the implementation of precision farming in agricultural operations along with the use of solar energy to reduce carbon emissions.
- The WEF Nexus concept is a well suited concept to study the basins in Turkey. Applying the concept to the other basins is of importance so that whole country profile can be obtained and then WEF Nexus concept that will include import materials from other countries can be applied.

SUSTAINABILITY OF THE GEDIZ BASIN-TURKEY:
A WATER – ENERGY AND FOOD NEXUS APPROACH

THANK YOU FOR YOUR ATTENTION !

by
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