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

by
Adnan DEGIRMENCIOGLU¹, Rabi H. MOHTAR², Bassel T. DAHER², Gulden O. ERTUGRUL³

¹Ege University, Faculty of Agriculture, Department of Agricultural Engineering & Technology, Bornova-İzmir, Turkey 35100
²Texas A&M University, Department of Biological and Agricultural Engineering, College Station-Texas, USA 77843
³Ahi Evran University, Faculty of Agriculture, Department of Biosystems Engineering, Kırşehir, Turkey 40100
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?
WATER

ENERGY

FOOD

Population growth

Climate change

Urbanization

Changes in sources

Changes in farming practices

Sustainability

New energy sources
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
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

- **Field crops**
  - Aydin: 9%
  - Denizli: 20%
  - Istanbul: 23%
  - Manisa: 48%
  - **Barley**: 6%
  - **Clover**: 2%
  - **Corn for silage**: 8%
  - **Corn**: 8%
  - **Cotton**: 3%
  - **Potato**: 2%
  - **Tobacco**: 3%
  - **Vetch**: 2%

- **Vegetables**
  - Aydin: 7%
  - Denizli: 7%
  - **Izmir**: 23%
  - Manisa: 56%
  - **Tomato**: 3%
  - **Cherry**: 3%
  - **Fig**: 4%
  - **Olive**: 24%
  - **Raisins**: 11%
  - **Table grape**: 5%

- **Fruits**
  - Aydin: 19%
  - Denizli: 19%
  - **Izmir**: 30%
  - Manisa: 53%
  - **Z- Fig**: 3%
  - **Z- Cherry**: 3%
  - **Z- Fig**: 4%
  - **Z- Olive**: 24%
  - **Z- Raisins**: 11%
  - **Z- Table grape**: 5%
  - **Z- Tomato**: 3%
  - **Z- Table grape**: 5%
  - **Z- Olive**: 24%
  - **Z- Raisins**: 11%
  - **Z- Table grape**: 5%
  - **Z- Tomato**: 3%
<table>
<thead>
<tr>
<th>Town</th>
<th>Production Area (ha)</th>
<th>Total production (tons)</th>
<th>Yield (t/ha)</th>
<th>Tractor Use (h/ha)</th>
<th>Average Tractor power (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buharkent</td>
<td>78.5</td>
<td>220</td>
<td>2.80</td>
<td>13.1</td>
<td>29.66</td>
</tr>
<tr>
<td>Köşk</td>
<td>50</td>
<td>185</td>
<td>3.70</td>
<td>13.1</td>
<td>34.15</td>
</tr>
<tr>
<td>Kuyucak</td>
<td>700</td>
<td>2,656</td>
<td>3.79</td>
<td>13.1</td>
<td>30.64</td>
</tr>
<tr>
<td>Nazilli</td>
<td>827.2</td>
<td>2,979</td>
<td>3.60</td>
<td>13.1</td>
<td>32.93</td>
</tr>
<tr>
<td>Sultanhisar</td>
<td>40</td>
<td>131</td>
<td>3.28</td>
<td>13.1</td>
<td>29.1</td>
</tr>
</tbody>
</table>
TRACTOR RUN TIME (Barley example)

13.1 h/ha
Consumption (L) = Q \times \text{Time spent per ha}

Q_{avg} = 0.223 \cdot P_{pto}

Q_{avg} = \text{average diesel fuel consumption (L/h)} \quad P_{pto} = \text{the rated PTO power, kW}
TRACTOR POWER DISTRIBUTION IN TOWNS

Maximum PTO power (HP)

<table>
<thead>
<tr>
<th>Town</th>
<th>Power (HP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aydin</td>
<td>42</td>
</tr>
<tr>
<td>Denizli</td>
<td>40</td>
</tr>
<tr>
<td>izmir</td>
<td>39</td>
</tr>
<tr>
<td>Manisa</td>
<td>37</td>
</tr>
<tr>
<td>Field crop</td>
<td>Gasoline consumption (L/ha)</td>
</tr>
<tr>
<td>----------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Barley</td>
<td>47.855</td>
</tr>
<tr>
<td>Dried beans</td>
<td>113.58</td>
</tr>
<tr>
<td>Table beans</td>
<td>38.055</td>
</tr>
<tr>
<td>Chick pea</td>
<td>82.55</td>
</tr>
<tr>
<td>Clover</td>
<td>43</td>
</tr>
<tr>
<td>Corn for silage</td>
<td>131</td>
</tr>
<tr>
<td>Corn</td>
<td>159.12</td>
</tr>
<tr>
<td>Cotton</td>
<td>222.03</td>
</tr>
<tr>
<td>Field crop</td>
<td>Seasonal water requirement (m³/ha)</td>
</tr>
<tr>
<td>---------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>Barley</td>
<td>4709.1</td>
</tr>
<tr>
<td>Dried beans</td>
<td>4790</td>
</tr>
<tr>
<td>Table beans</td>
<td>4790</td>
</tr>
<tr>
<td>Chick pea</td>
<td>4680.9</td>
</tr>
<tr>
<td>Clover</td>
<td>10143.8</td>
</tr>
<tr>
<td>Corn for silage</td>
<td>2530</td>
</tr>
</tbody>
</table>

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

- Manisa (Rain fed): 48%
- Manisa (Irrigated): 5%
- Aydın (Rain fed): 2%
- Aydın (Irrigated): 13%
- İzmir (Rain fed): 11%
- İzmir (Irrigated): 0%
- Denizli (Rain fed): 17%
- Denizli (Irrigated): 4%
## FERTILIZER RATES (kg/ha)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Nitrate (kg/ha)</th>
<th>Phosphate (kg/ha)</th>
<th>Potassium (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>90</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>Beans (Dried)</td>
<td>252.7</td>
<td>69.4</td>
<td>43.8</td>
</tr>
<tr>
<td>Beans for table</td>
<td>90</td>
<td>125</td>
<td>150</td>
</tr>
<tr>
<td>Chick pea</td>
<td>40</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>Clover</td>
<td>132.1</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>Corn</td>
<td>272.7</td>
<td>166.6</td>
<td>0</td>
</tr>
<tr>
<td>Corn for silage</td>
<td>272.7</td>
<td>166.6</td>
<td>0</td>
</tr>
<tr>
<td>Cotton</td>
<td>185.4</td>
<td>125</td>
<td>0</td>
</tr>
</tbody>
</table>
## FINANCIAL VALUE (TL/ton – TIE 2014)

<table>
<thead>
<tr>
<th>Field Crop</th>
<th>Domestic Financial Value (TL/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>620</td>
</tr>
<tr>
<td>Beans (Dried)</td>
<td>3690</td>
</tr>
<tr>
<td>Beans for table</td>
<td>1920</td>
</tr>
<tr>
<td>Chick pea</td>
<td>2330</td>
</tr>
<tr>
<td>Clover</td>
<td>520</td>
</tr>
<tr>
<td>Corn</td>
<td>620</td>
</tr>
<tr>
<td>Corn for silage</td>
<td>280</td>
</tr>
<tr>
<td>Cotton</td>
<td>1470</td>
</tr>
</tbody>
</table>
## ENERGY AND CARBON EMISSION DATA

### Energy need (kJ/kg)

<table>
<thead>
<tr>
<th>Nitrogen</th>
<th>Phosphorus</th>
<th>Potassium</th>
</tr>
</thead>
<tbody>
<tr>
<td>78230</td>
<td>17500</td>
<td>13800</td>
</tr>
</tbody>
</table>

### Energy need for water (kWh/m³)

<table>
<thead>
<tr>
<th>Source</th>
<th>Energy need</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwater</td>
<td>0.4068</td>
</tr>
<tr>
<td>Surface water by GDSHW</td>
<td>0.209</td>
</tr>
<tr>
<td>Groundwater by Solar Energy Solar</td>
<td>0.406</td>
</tr>
</tbody>
</table>

### Carbon emissions of different sources

<table>
<thead>
<tr>
<th>Source</th>
<th>Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel gasoline*</td>
<td>0.002357 tons CO₂/L or 778 g CO₂/kWh</td>
</tr>
<tr>
<td>N, P and K fertilizers**</td>
<td>0.0026 tons/ kg</td>
</tr>
<tr>
<td>Hydroelectric power***</td>
<td>24 g CO₂/kWh</td>
</tr>
<tr>
<td>Solar panel toproof***</td>
<td>32 CO₂/kWh</td>
</tr>
</tbody>
</table>
Near Future Scenarios

Long Term Scenarios
Both, climate change and solar energy use were considered in the near future scenarios.
CLIMATE CHANGE CONSIDERATIONS IN THE NEAR FUTURE SCENARIOS

For the seasonal water requirement (mm):
- Linear fit for the coldest year: $y = 0.8785x$, $R^2 = 0.9991$
- Linear fit for the warmest year: $y = 1.0957x$, $R^2 = 0.9991$

For the water available to the plant (mm):
- Linear fit for the coldest year: $y = 0.6184x - 21.735$, $R^2 = 0.9283$
- Linear fit for the warmest year: $y = 0.9106x + 45.973$, $R^2 = 0.9105$
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
- **NFC SSE0**: Cold season and no solar energy used
- **NFC SSE05**: Cold season with 5% solar energy use
OUTPUT FOR THE YEAR 2014 - NFNSSE0 (top 15 crops)

Normal season and no solar energy used

<table>
<thead>
<tr>
<th>W</th>
<th>Water (m³)</th>
<th>1062105011.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>Land (ha)</td>
<td>529857.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>£</th>
<th>$E_{W} (kJ)$</th>
<th>886595982226.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>£</td>
<td>$E_{SWA} (kJ)$</td>
<td>0.0</td>
</tr>
<tr>
<td>£</td>
<td>$E_{SWB} (kJ)$</td>
<td>343624968696.4</td>
</tr>
</tbody>
</table>

| £   | $E_{s} (kJ)$ | 1.23022E+12    |

<table>
<thead>
<tr>
<th>£</th>
<th>$E_{d} (kJ)$</th>
<th>2210083923920.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>£</td>
<td>$E_{r} (kJ)$</td>
<td>170693673987.2</td>
</tr>
<tr>
<td>£</td>
<td>$E_{f} (kJ)$</td>
<td>6920075184949.7</td>
</tr>
</tbody>
</table>

| £   | $E_{s} = E_{d} + E_{r} (kJ)$ | 1.05311E+13    |

<table>
<thead>
<tr>
<th>£</th>
<th>$F_{local} (TL)$</th>
<th>6733675566.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>£</td>
<td>$F_{import} (TL)$</td>
<td>0</td>
</tr>
</tbody>
</table>

| £   | $F (TL)$ | 6733675566    |

<table>
<thead>
<tr>
<th>£</th>
<th>$C_{SWA} (tons)$</th>
<th>5910.64</th>
</tr>
</thead>
<tbody>
<tr>
<td>£</td>
<td>$C_{SWB} (tons)$</td>
<td>74261.2</td>
</tr>
</tbody>
</table>

| £   | $C_{t} (tons)$ | 80171.8        |

| £   | $C_{W} (tons)$ | 365676.9       |

| £   | $C_{t} = C_{1} + C_{2} (tons)$ | 600010.6       |

| £   | $C_{t} (tons)$ | 519838.7       |

| £   | $C_{r} (tons)$ | 11052.9        |

| £   | $C_{m} (tons)$ | 143109.0       |
Normal season and no solar energy used

<table>
<thead>
<tr>
<th>Water (m³)</th>
<th>Water saving (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td></td>
</tr>
<tr>
<td>Water (m³)</td>
<td>275473062.6</td>
</tr>
<tr>
<td>Water saving (m³)</td>
<td>0</td>
</tr>
<tr>
<td>Land (ha)</td>
<td>84059.9</td>
</tr>
<tr>
<td>Land saving (ha)</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Energy (kJ)</th>
<th>E₁ (kJ)</th>
<th>E₂ (kJ)</th>
<th>E₁+E₂ (kJ)</th>
<th>Eₚₑₚ (kJ)</th>
<th>C₁ (tons)</th>
<th>C₂ (tons)</th>
<th>C (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E₁</td>
<td></td>
<td></td>
<td></td>
<td>1.87041E+12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E₂</td>
<td></td>
<td></td>
<td></td>
<td>1.55134E+12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eₚₑₚ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C₁</td>
<td>1533.014205</td>
<td></td>
<td></td>
<td></td>
<td>20793.8</td>
<td></td>
<td>117225.2</td>
</tr>
<tr>
<td>C₂</td>
<td>26583.2</td>
<td>2083.6</td>
<td>96431.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

W: Water (m³) 275473062.6
L: Land (ha) 84059.9

F: Energy (kJ)
- Eₚₚ (kJ)
- E₁ (kJ)
- E₂ (kJ)
- E₁+E₂ (kJ)
- Eₚₑₚ (kJ)

C: Material (tons)
- C₁ (tons)
- C₂ (tons)
- C (tons)

Eₚₑₚ: Energy from pumping and irrigation
Eₚₚ: Energy from pumping and irrigation
C: Material (tons)
C₁: Material (tons)
C₂: Material (tons)
C (tons): Total material (tons)
**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 \( \Delta \) represents the change in parameter value from base.

<table>
<thead>
<tr>
<th>( O_b )</th>
<th>( O )</th>
<th>( O - O_b )</th>
<th>( P_{(b \pm \Delta)} )</th>
<th>( P_b )</th>
<th>( P_{(b \pm \Delta) - P_b} )</th>
<th>( P_b/O_b )</th>
<th>( S_r )</th>
</tr>
</thead>
<tbody>
<tr>
<td>W (m³)</td>
<td>1337578074</td>
<td>1334973352</td>
<td>-2604722.023</td>
<td>0.8</td>
<td>-0.2</td>
<td>7.4762E-10</td>
<td>0.009737</td>
</tr>
</tbody>
</table>

Source: Daher, 2012
WATER SENSITIVITY RATIO

![Graph showing water sensitivity ratio for various crops](image-url)

- Barley
- Clover
- Corn for silage
- Corn
- Cotton
- Potato
- Tobacco
- Vetch
- Wheat
- X-Tomato
- Z-Cherry
- Z-Fig
- Z-Olive
- Z-Raisins
- Z-Table grape

The graph illustrates the water sensitivity ratio for different crops, with Z-Raisins having the highest sensitivity.
ENERGY SENSITIVITY RATIO

\[ E_1 = E_{\text{GWe}} + E_{\text{GWs}} + E_{\text{SW}} \]

\[ E_2 = E_{\text{farming}} + E_{\text{transport}} + E_{\text{fert}} \]
The diagram illustrates the Carbon Sensitivity Ratio (C) for various crops. The ratio is represented as:

\[ C = C_1 + C_2 \]

Where:

\[ C_1 = C_{GWe} + C_{GWs} + C_{SW} \]
\[ C_2 = C_{farming} + C_{transport} + C_{fert} \]
GROUPING CROPS BASED ON THE SENSITIVITY RATIOS

![Graph showing the grouping of crops based on sensitivity ratios.](image-url)
WATER REQUIREMENTS IN NEAR FUTURE SCENARIOS

W (m$^3$)
ENERGY REQUIREMENTS IN NEAR FUTURE SCENARIOS

E (kJ)

1.1E+13  1.15E+13  1.2E+13  1.25E+13  1.3E+13  1.35E+13

NFNSSE0  NFNSSE5  NFHSSE0  NFHSSE5  NFCSSE0  NFCSSE5
CARBON EMISSIONS IN NEAR FUTURE SCENARIOS

C (ton CO₂)

x 10000

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Emissions (ton CO₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NFNSSE0</td>
<td>64</td>
</tr>
<tr>
<td>NFNSSE5</td>
<td>66</td>
</tr>
<tr>
<td>NFHSSE0</td>
<td>68</td>
</tr>
<tr>
<td>NFHSSE5</td>
<td>70</td>
</tr>
<tr>
<td>NFCSSE0</td>
<td>68</td>
</tr>
<tr>
<td>NFCSSE5</td>
<td>66</td>
</tr>
</tbody>
</table>
Sustained Indicators

\[ \text{S.I. } i = \left[ \text{Wi}_i (100-\text{I}_W) + \text{Li}_i (100-\text{I}_L) + \text{El}_i (100-\text{I}_E) + \text{Cl}_i (100-\text{I}_C) + \text{Fl}_i (100-\text{I}_F) + \right. \\
\left. \text{EIMP }_i (100-\text{I}_{EIMP}) + \text{CIMP }_i (100-\text{I}_{CIMP}) \right] / 100 \]

\( \text{Wi} = \) the total water needed for scenario \( i \)
\( \text{Li} = \) the total land area needed for scenario \( i \)
\( \text{El} = \) the total local energy needed for scenario \( i \)
\( \text{Cl} = \) the total local carbon emitted by scenario \( i \)
\( \text{Fl} = \) the total finances for scenario \( i \)

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

\[ \text{I}_W + \text{I}_L + \text{I}_E + \text{I}_C + \text{I}_F + \text{I}_{EIMP} + \text{I}_{CIMP} = 100 \]

Assessment parameters
SUSTAINABILITY INDEX FOR NEAR FUTURE SCENARIOS
LONG TERM SCENARIOS (CLIMATE CHANGE)

Seasonal water requirement (mm)

Coldest year
Warmest year
Linear (Coldest year)
Linear (Warmest year)

Water available to the plant (mm)

Coldest year
Warmest year

y = 0.8785x
R² = 0.9991

y = 1.0957x
R² = 0.9991

y = 0.6184x - 21.735
R² = 0.9283

y = 0.9106x + 45.973
R² = 0.9105

y = 0.9106x + 45.973
R² = 0.9105

y = 0.9106x + 45.973
R² = 0.9105

y = 0.6184x - 21.735
R² = 0.9283

y = 0.6184x - 21.735
R² = 0.9283
URBANIZATION

\[ y = -13480x + 3 \times 10^7 \]

\[ R^2 = 0.5621 \]
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.

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.
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 refers to Urbanization and in this year land size was reduced by ... %

- **2040**
  - Land size was reduced by ... %

- **2050**
  - 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

2030UNSSE0  →  Normal season and no solar energy used
2030UNSSE5  →  Normal season with %5 solar energy use
2040UNSSE0  →  Normal season and no solar energy used
2040UNSSE10 →  Normal season with %10 solar energy use
2050UNSSE0  →  Normal season and no solar energy used
2050UNSSE15 →  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

CHANGES IN LOCAL COSTS IN LONG TERM SCENARIOS

CHANGES IN LOCAL COSTS IN LONG TERM SCENARIOS

CHANGES IN LOCAL COSTS IN LONG TERM SCENARIOS
WATER REQUIREMENTS IN LONG TERM SCENARIOS
ENERGY NEEDS IN LONG TERM SCENARIOS

E (kJ)

100000
105000
110000
115000
120000
125000
130000

x 100000000

E (kJ)

100000
104000
108000
112000
116000
120000
124000

x 100000000

E (kJ)

105000
110000
115000
120000
125000
130000

x 100000000
CARBON EMISSIONS IN LONG TERM SCENARIOS

C (tons)

C (tons)

C (tons)
SUSTAINABILITY INDEX IN LONG TERM SCENARIOS

[Bar chart showing sustainability index values for various scenarios labeled 2030UCSSE0, 2030UCSSE5, 2030UCSSW53SE0, 2030UCSSW53SE5, 2030UHSSE0, 2030UHSSE5, 2030UHSSW53SE0, 2030UHSSW53SE5, 2030UNSSSE0, 2030UNSSSE5, 2030UNSSSW53SE0, 2030UNSSSW53SE5.]
SUSTAINABILITY INDEX IN LONG TERM SCENARIOS
TRADEOFFS – REDUCTION IN SELF SUFFICIENCY vs POPULATION GROWTH

\[ y = 860458x - 2 \times 10^9 \]
\[ R^2 = 0.9901 \]

\[ y = 2738x - 5 \times 10^6 \]
\[ R^2 = 0.7455 \]
TRADEOFFS – REDUCTION IN PRODUCTION vs EXPORT
TRADEOFFS – REDUCTION IN PRODUCTION vs EXPORT

![Graph showing tradeoffs between reduction in production and export over years 2014 to 2050 for different crops (Example: Apricot, Tomato)].

- **Apricot**
  - 2014: 0.011
  - 2030: 0.0112
  - 2040: 0.0114
  - 2050: 0.0116

- **Tomato**
  - 2014: 0.124
  - 2030: 0.122
  - 2040: 0.118
  - 2050: 0.114

The graphs illustrate the tradeoffs with respect to different years and crops, showing how changes in production and export affect each other.
Increase in surface water use from 43 to 53% and cold season may help the recovery of groundwater depth.
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.
• 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

Adnan DEĞIRMENCİOĞLU\textsuperscript{1}, Rabi H. MOHTAR\textsuperscript{2}, Bassel T. DAHER\textsuperscript{2}, Gulden O. ERTUGRUL\textsuperscript{3}

\textsuperscript{1}Ege University, Faculty of Agriculture, Department of Agricultural Engineering & Technology, Bornova-İzmir, Turkey 35100
\textsuperscript{2}Texas A&M University, Department of Biological and Agricultural Engineering, College Station-Texas, USA 77843
\textsuperscript{3}Ahi Evran University, Faculty of Agriculture, Department of Biosystems Engineering, Kırşehir, Turkey 40100