AQUITOPIA (An Aquifer Management-based Utopia),
Gareh Bygone Plain, Islamic Republic of Iran

Progress Report of SUMAMAD Activities

2011
AQUITOPIA (An Aquifer Management-based Utopia), Gareh Bygone Plain, Islamic Republic of Iran

Annual Report for the Year of 2011

1. Project Site Information

a. Name of project site
Gareh Bygone Plain, Islamic Republic of Iran

b. Name of Project
AQUITOPIA (An Aquifer Management-based Utopia), Gareh Bygone Plain, Islamic Republic of Iran

c. Partner Institution
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2. Executive Summary

The Sustainable Management of Marginal Drylands (SUMAMAD) project is being carried out under the aegis of UNU-INWEH and UNESCO-MAB. The Iranian project was initiated to study the role of aquifer management on different aspects of desertification control through floodwater harvesting. The Research Society for Sustainable Rehabilitation of Drylands (REaSSURED) – a registered scientific NGO – is responsible for planning and implementing the project in the Islamic Republic of Iran. AQUITOPIA (an aquifer management-based utopia) – a project proposed in Phase 2 of the SUMAMAD project – is being governed by an executive committee comprised of representatives from four local cooperatives and REaSSURED experts. The SUMAMAD Phase 2 broad objectives for the Iranian case study consist of scientific studies, policy-relevant analyses, and activities for fostering sustainable livelihoods.

The main proposed activities for the 2nd Phase of the SUMAMAD project in Iran are as follows:

a. Empowerment of the four cooperative members to complete, manage and benefit from the AQUITOPIA project;
b. The introduction of income-generating alternatives;
c. Capacity building for cooperative members in soil and water conservation technologies;
d. Continuation of research activities started during the 1st phase of SUMAMAD;
e. Implementation of the newly proposed research activities for the 2nd Phase of the SUMAMAD project;
f. Sharing of experiences gained in the field of water harvesting and soil and water conservation technologies through the sustainable development of drylands with other countries involved in the SUMAMAD project; and
g. Encouraging the Iranian Government authorities to fund the AQUITOPIA project.

In 2009, a floodwater-spreading system was installed over 162 ha using USD 220,000 provided by SUMAMAD and the Government of the Islamic Republic of Iran. This operation included 38,117.76 m³ of earthworks and 2,631.2 m³ of masonry hydraulic structures. In 2010, floodwater-spreading systems were constructed over 120 ha using USD 50,000 allocated by the Government of Iran in Ahmadabad – the site of the AQUITOPIA project. The Fars Research Centre for Agriculture and Natural Resources undertook surveys for this operation.

Of the 10 approved activities for the 2nd Phase of the SUMAMAD Programme for the Iranian case study, four were completed by 2010 and one is due to be completed by the end of 2011. Sowbug studies, spate irrigation of barley, honey production, and socio-economic analysis of income-generating alternatives in the Gareh Bygone Plain ended in 2010, and empowerment of local cooperatives is due to be completed by the end of 2011. The present annual report comprises six ongoing activities.

The elimination of subsides, combined with a national economic plan implemented in late 2010, and the high rate of inflation (influenced in part by the global economic crises and sanctions), led to a substantial increase in the majority of expenses in both the governmental and private sectors. As a consequence, rural people avoided participation in any new activity without specific benefits or government guarantees. This context and the scarcity of government funding were the principle reasons why certain planned activities, such as local cooperatives empowerment and laboratory services, did not materialize.
3. Introduction
The project acquired 1,070 ha of a degraded rangeland near Ahmad Abad village in the SW of Gareh Bygone Plain (GBP 28°35´N; 53°53´ E; 1,150 m above sea level, 210 km S.E. of Shiraz, Iran). This project is based on aquifer management (AM), which involves application of floodwater spreading (FWS) for the artificial recharge of groundwater (ARG), as well as the improvement of water-use efficiency (WUE). The inhabitants of four farming communities surrounding the AQUITOPIA project site were convinced to form cooperatives to construct the ARG system, and thus benefit from managing the aquifer for specific purposes. The cooperatives were duly registered.

The study phase of the project began with a grant donated by UNU in 2003. SUMAMAD and the Iranian government financed construction of 230 ha of ARG systems. The construction of the remaining ARG system (398 ha) necessitated drilling water wells, equipping them with pumping stations, laser land levelling (451 ha) and tree planting, all of which cost about USD 2.5 million. Another USD 3 million would be required to establish a ‘green village’ for 110 households. The bulk of funds will be provided through low interest, long-duration loans supplied to the cooperatives by the Iranian government. Assuming that the necessary funds are received, the construction phase of the project will be completed by December 2013.

4. Specific objectives
The specific objectives of the project are as follows:

- The supply of irrigation and safe drinking water.
- The construction of a green village, providing livelihoods for 110 households.
- The implementation of integrated natural resources management and research projects (water productivity in agriculture, rangeland management, horticulture, animal husbandry, bee-keeping and conservation of natural resources).
- The provision of good quality, coarse-grained alluvial aquifers, which are valued higher than oil supplies by desert dwellers.
- Demonstrable proof that, if used wisely, a sub-marginal resource (the degraded rangelands) and a marginal resource (floodwater) can provide a decent livelihood for desert dwellers.

5. Major activities
The major activities of the Iranian case are as follows:

- The completion and maintenance of 230 ha of FWS started during Phase I of the SUMAMAD project, and benefitting from the government funding.
- The construction of a new FWS system over 398 ha for the artificial recharge of groundwater.
- The preparation of 451 ha of farm fields for irrigation by laser levelling.
- The registration of two additional local cooperatives.
- The implementation of action research projects for the wise management of natural resources.
- Capacity-building of cooperative members to enable them to act as honorary extension agents.
- The introduction of income-generating alternatives to the cooperatives.
- The introduction of soil and water-conservation technologies to the cooperatives.
• Networking with environment-related NGOs.
• Campaigning for the inclusion of aquifer management in global water-harnessing policy.

6. Annual progress report of Iran’s sub-projects in 2011
The sub-projects’ annual report of SUMAMAD-2 in Gareh Bygone Plain, Iran, for 2011 is presented below. The report focuses on technical, environmental and socio-economic assessments of activities conducted at the study site.

6.1. Efficiency of floodwater spreading on net recharge of the aquifer, Gareh Bygone, Iran
Mojtaba Pakparvar, Fars Research Center for Agriculture and Natural Resources & REaSSURED

Introduction
Despite the obvious positive impacts of floodwater spreading (FWS) on groundwater recharge and the rehabilitation of a sandy desert environment in the Gareh Bygone Plain, there is a permanent recession trend in the groundwater level in its aquifer. In order to quantify the role of FWS on net recharge, the water balance components, including the intake and uptake parts, need to be known. Pumping water for agriculture, and uptake of water by trees planted in the project area are the main uptake sources of reserved groundwater. However, the exact amount is unknown. As a rule of thumb, hydrologic balance studies cannot achieve a close estimate of water withdrawal; instead, a methodical soil hydrologic balance study must be undertaken.

The objective of this research is to determine the portion of diverted floodwater that contributes to net recharge in a basin in the GBP. This is achieved by collecting scientifically approved data showing the real impact of FWS on net recharge. This would help to inform GBP decision-makers of ways to manage water withdrawal to guarantee the sustainable management of groundwater by stopping or reversing the recession trend. Quantified results will also clarify the importance of FWS for dissemination as an environmentally friendly, small-scale water-harvesting project.

The objectives are more suited to the first outline of the SUMAMAD Project (fostering scientific drylands research), described as the improvement of dryland agriculture (crop and livestock production) through the sustainable use of natural resources, focusing on sustainable water conservation and harvesting practices.

In order to reach the target, the physical behaviour of the vadose zone must first be studied. Second, the downward and upward movement of water through the profile between flooding events must be controlled. The results will then be applied for soil-water flux simulation, and finally the net recharge calculation. The plan of action (PAC) is summarized below:

1. Soil-water studies
1-1. Piezometric level data collection and analysis
1-2. Field works in the Gareh Bygone Plain (study site in Iran)
1-2-1. Implementation the main setup of one of the experimental wells
1-2-2. Characterization of the vadose zone materials based on the profile layers, including determination of infiltration rate, bulk density, texture and layer description
1-2-3. Calibration of the Time Domain Reflectometers (TDR) sensors
1-2-4. Insulation of one of the experimental wells
1-2-5. Soil moisture monitoring during flooding intervals
1-2-6. Simulation of water movement through the vadose zone
1-3. Surface topography of the study basin

2. Plant-water studies
2-1. Sap flow measurement to determine transpiration rate of the planted trees
2-2. Application of remote sensing for seasonal actual evapotranspiration mapping

*Determination of the net recharge in flooding events based on a soil-water balance approach*

The study area is located in a floodwater spreading system called Bisheh Zard_1 (BZ_1), covering 27.25 ha, part of the Kowsar research station in Gareh Bygone Plain. (Figures 1)

*Activities*

Although the sap flow study was considered the topmost priority, failure to obtain a complete set of sap flow meters resulted in the prioritization of soil-water studies. Sections 1-1 to 1-2-4 of the PAC then concentrated on finalization of the soil-water studies, including section 1-2-6. The plant-water study was also initiated and focused on the sap flow meter studies (section 2-1). At the end of 2010, soil-water studies resulted in preparation of an experimental well. The well is
equipped with TDR sensors and its wall is insulated to avoid lateral movement of water into the well (Figure 3). Plant-water studies were initiated in the same year with the installation of sap flow sensors on a typical tree in the study area. Measurements taken by the TDR sensors and sap flow devices continued until the end of 2010.

Activities outlined for sections 1-2-6 and 2-1 continued in 2011. In addition, section 2-2 was begun and finalized in the same year.

Figure 3. Isolation of the wall of the experimental well. © Mojtaba Pakparvar, REaSURED, Iran, 2011

Figure 4. Installation of the TDR cables in an experimental well (left) and TDR readings after the flooding event in February 2011 (right). © Ali Fereidoonian, FRCANR, Iran, 2011.

Monitoring soil moisture of the vadose zone layers during flooding intervals
Soil moisture measurement at specific depths of the well wall began in August 2010 and continued at weekly intervals. The occurrence of a flood on 31 January 2011 triggered the start of the expected research focus. Measurements were taken at twice daily intervals from 31 of January to 21 of March 2011 (Figure4), then changed to weekly intervals.
Figure 5. Floodwater spreading on the study site (second strip of the BZ₁) in February 2011. © Ali Fereidoonian, FRCANR, Iran, 2011.
Rainfall depth and volume of water harvested by the FWS system
A standard rain gauge is being used to measure the amount of rainfall at a weather station located in the study area. The height of floodwater in the main stream, and the part diverted into the FWS system, is being recorded at two hydrometry stations (Figures 6 and 7).

Figures 6 and 7. Hydrometry stations in the main ephemeral river, the Bisheh Zard (top) and on an inundation canal, which diverts floodwater to the FWS system (bottom). © Ali Fereidoonian, FRCANR, Iran, 2011
Sap flow measurement for transpiration studies of planted trees
The placement of the sap flow meter was changed to another recharge basin in the study area in July 2011, in order to collect data from a tree with certain specifications.

A 25-year-old *Eucalyptus camaldulensis* Dehnh. tree, a representative of a dense forest in the study area, was selected and a sap flow meter installed on its trunk at a height of 6 metres (Figures 8 and 9). The meter measures and records sap flow at 15-minute intervals.

![Figures 8 and 9. Sap flow meter installation and measurement on a eucalyptus tree in the Gareh Bygone Plain in July 2011. Hamid Mesbah, FRCANR, Iran, 2011.](image)
Application of remote sensing for actual seasonal evapotranspiration mapping
Actual evapotranspiration was calculated for an extensive area covered by various crops and planted trees (20-27-years old *Eucalyptus camaldulensis* and *Acacia victoriae*) in the GBP. Landsat 5 TM images with a time sequence between May 2009 and October 2010 (42 images) were processed and dynamic land cover maps produced for each time interval by visual interpretation on the basis of the field data. The Surface Energy Balance System (SEBS) model and r.sun module in the GRASS-GIS were evaluated for net radiation estimation, and the SEBS for actual evapotranspiration (ET) prediction at the local scale using meteorological data. This research step aimed to evaluate the performance of the SEBS model for mapping the ET\(_a\) over long-term duration.

**Preliminary results obtained**
Some of the preliminary results were published in a national journal (Ghahari et al., 2009) and presented at the National SUMAMAD Workshops. The full texts are published in the workshop proceedings (Pakparvar, 2010; Pakparvar and Hashemi, 2010). Some of the prominent results obtained in 2011 were as follows:

**Flooding and rainfall data**
The data for rainfall and flooding for the January–February 2011 event are presented in Tables 1 and 2, respectively. During the period of TDR measurements, rainfalls were mainly concentrated in late February to mid-March 2011. The main event lasted from 27 January to 3 February 2011. A total amount of 145 mm of rain was recorded. Flooding started on 31 January and continued to 3 February 2011. During those days 49 hours of flood flow were recorded.

Table 1. Rainfall data during the period of TDR measurement

<table>
<thead>
<tr>
<th>Day</th>
<th>Evaporation (mm)</th>
<th>Rainfall (mm) 6:30</th>
<th>Rainfall (mm) 18:30</th>
<th>Day</th>
<th>Evaporation (mm)</th>
<th>Rainfall (mm) 6:30</th>
<th>Rainfall (mm) 18:30</th>
</tr>
</thead>
<tbody>
<tr>
<td>21 Jan</td>
<td>2.6</td>
<td>-</td>
<td>-</td>
<td>6 Feb</td>
<td>4.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>22 Jan</td>
<td>2.9</td>
<td>-</td>
<td>-</td>
<td>7 Feb</td>
<td>3.5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>23 Jan</td>
<td>2.6</td>
<td>-</td>
<td>-</td>
<td>8 Feb</td>
<td>3.9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>24 Jan</td>
<td>2.6</td>
<td>-</td>
<td>-</td>
<td>9 Feb</td>
<td>2.9</td>
<td>11.0</td>
<td>5.5</td>
</tr>
<tr>
<td>25 Jan</td>
<td>2.8</td>
<td>-</td>
<td>-</td>
<td>10 Feb</td>
<td>2.3</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>26 Jan</td>
<td>2.7</td>
<td>- 0.5</td>
<td>2</td>
<td>11 Feb</td>
<td>2.0</td>
<td>- 2.0</td>
<td></td>
</tr>
<tr>
<td>27 Jan</td>
<td>2.0</td>
<td>11.0</td>
<td>1.5</td>
<td>12 Feb</td>
<td>2.9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>28 Jan</td>
<td>2.0</td>
<td>15.0</td>
<td>1.0</td>
<td>13 Feb</td>
<td>2.2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>29 Jan</td>
<td>2.6</td>
<td>-</td>
<td>-</td>
<td>14 Feb</td>
<td>2.6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>30 Jan</td>
<td>2.6</td>
<td>-</td>
<td>-</td>
<td>15 Feb</td>
<td>3.1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>31 Jan</td>
<td>2.0</td>
<td>25.0</td>
<td>29.5</td>
<td>16 Feb</td>
<td>3.1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1 Feb</td>
<td>1.7</td>
<td>9.0</td>
<td>43.0</td>
<td>17 Feb</td>
<td>2.1</td>
<td>10.0</td>
<td></td>
</tr>
<tr>
<td>2 Feb</td>
<td>2.0</td>
<td>9.0</td>
<td>-</td>
<td>18 Feb</td>
<td>2.6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3 Feb</td>
<td>2.8</td>
<td>4.5</td>
<td>-</td>
<td>19 Feb</td>
<td>3.5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4 Feb</td>
<td>2.6</td>
<td>-</td>
<td>total</td>
<td>81.1</td>
<td>85.5</td>
<td>93.0</td>
<td></td>
</tr>
<tr>
<td>5 Feb</td>
<td>3.5</td>
<td>-</td>
<td>Grand total</td>
<td>178.5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2. Flood flow data

<table>
<thead>
<tr>
<th>Date</th>
<th>Rainfall Start</th>
<th>Rainfall End</th>
<th>Rainfall mm</th>
<th>Flood duration Start</th>
<th>Flood duration End</th>
<th>Floodwater volume</th>
<th>Diverted volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>31 Jan</td>
<td>12:00 PM</td>
<td>6:30 PM</td>
<td>54</td>
<td>4:00 AM</td>
<td>10:00 AM</td>
<td>1,242,000</td>
<td>993,600</td>
</tr>
<tr>
<td>1 Feb</td>
<td>6:30 AM</td>
<td>6:30 AM</td>
<td>9</td>
<td>10:00 AM</td>
<td>3:00 AM</td>
<td>4,865,400</td>
<td>2,432,700</td>
</tr>
<tr>
<td>2 Feb</td>
<td>6:30 AM</td>
<td>6:30 AM</td>
<td>43</td>
<td>3:00 AM</td>
<td>3:00 AM</td>
<td>486,000</td>
<td>388,800</td>
</tr>
<tr>
<td>3 Feb</td>
<td>6:30 PM</td>
<td>6:30 AM</td>
<td>9</td>
<td>12:00 PM</td>
<td>5:00 AM</td>
<td>6,211,800</td>
<td>3,105,900</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>115</td>
<td></td>
<td>49</td>
<td>12,805,200</td>
<td>6,921,000</td>
</tr>
</tbody>
</table>

Soil water changes in the vadose zone due to artificial groundwater recharge
Changes in water content of the vadose zone layers are depicted in Figure 9. It was observed that soil moisture content of all layers is relatively constant before the flooding event.
There was an instant change in soil water content (SWC) after initiation of recharge. It took less than 24 hours for the wetting front to reach a depth of 400 cm. SWC remained constant in the deeper layers before and after the flooding event. Therefore, the saturated flow created the mass movement from the surface to the mentioned depth. Soil water movement will shift to an unsaturated state from 400 cm downward to an uncertain depth depending on many parameters. However, the piston is expected in later recharge events. The change in SWC in the soil profile due to rainfall and flooding is summarized in Table 3.

Table 3. The change in SWC due to the recharge event of January–February 2011

<table>
<thead>
<tr>
<th>Depth of layer (cm)</th>
<th>Depth intervals (cm)</th>
<th>Min SWC %</th>
<th>Max SWC %</th>
<th>Difference %</th>
<th>Recharged water (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>10</td>
<td>3.1</td>
<td>22.6</td>
<td>19.5</td>
<td>1.95</td>
</tr>
<tr>
<td>40</td>
<td>30</td>
<td>5.6</td>
<td>16.5</td>
<td>10.9</td>
<td>3.27</td>
</tr>
<tr>
<td>60</td>
<td>30</td>
<td>8.9</td>
<td>25.7</td>
<td>16.8</td>
<td>5.04</td>
</tr>
<tr>
<td>80</td>
<td>30</td>
<td>4.8</td>
<td>12.6</td>
<td>7.8</td>
<td>2.34</td>
</tr>
<tr>
<td>110</td>
<td>30</td>
<td>5.5</td>
<td>21.6</td>
<td>16.1</td>
<td>4.83</td>
</tr>
<tr>
<td>140</td>
<td>30</td>
<td>5.0</td>
<td>18.0</td>
<td>13.0</td>
<td>3.9</td>
</tr>
<tr>
<td>170</td>
<td>30</td>
<td>7.5</td>
<td>22.1</td>
<td>14.6</td>
<td>4.38</td>
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<td>200</td>
<td>30</td>
<td>9.8</td>
<td>23.1</td>
<td>13.3</td>
<td>3.99</td>
</tr>
<tr>
<td>230</td>
<td>30</td>
<td>8.5</td>
<td>18.9</td>
<td>10.4</td>
<td>3.12</td>
</tr>
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<td>260</td>
<td>30</td>
<td>9.1</td>
<td>14.7</td>
<td>5.6</td>
<td>1.68</td>
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<tr>
<td>290</td>
<td>30</td>
<td>7.5</td>
<td>12.1</td>
<td>4.6</td>
<td>1.38</td>
</tr>
<tr>
<td>400</td>
<td>110</td>
<td>8.9</td>
<td>17.4</td>
<td>8.5</td>
<td>9.35</td>
</tr>
<tr>
<td>Infiltrated water (cm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>45.23</td>
</tr>
<tr>
<td>Infiltrated water (m)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.45</td>
</tr>
<tr>
<td>Infiltrated water in one hectare (m³)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4,523</td>
</tr>
<tr>
<td>Total infiltrated water in 1524 hectare (m³)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4 650 480</td>
</tr>
</tbody>
</table>
Total floodwater diverted to the FWS (m$^3$) 6 921 000

Subtracting the depth of rainfall from the recharged water shows that 305 mm of the infiltrated water was due to the harvested floodwater. Assuming that the research site is representative of the 2033 ha ARG system in the GBP, and that only 75% of the system functioned as desired, upwards of 4.65 million m$^3$ was harvested in that event. This emphasizes the adequacy of surface permeability in permitting the floodwater to enter the deeper layers. This obviously negates the hypothesis of soil surface clogging due to sedimentation in the FWS systems. The remaining parts of the research project will provide the necessary data to quantify the exact quota of each component of water balance.

This will help to implement a systemic approach for water consumption on the basis of eventual recharge in order to provide contingency groundwater reserves for future droughty periods, and to prevent saltwater intrusion into the freshwater aquifers in the Gareh Bygone Plain.

**ET mapping**

Spatial maps and temporal signatures for land uses of interest were prepared and compared with the reference ET from the meteorological stations. Surface flux predictions from both methods performed very well when assessed against *in situ* flux measurements derived from the stations. Results of the r.sun module gave a better fit to the observed data.

Changes in the parameters have resulted in substantial improvement in the fitness of the SEBS predictions. Relative root mean square error and $r^2$ have been changed from 14.2% to 12.4% and 0.55 to 0.72, respectively, relative to before and after atmospheric correction. Incorporating the maximum wind speed has also improved these two statistics from 12.0% to 7.1% and 0.81 to 0.94, respectively. Incorporation of directly measured vegetation height for the forested area and rangeland in the map has resulted in outlying values of actual ET for forest pixels.

The generated maps for two representative months in winter and summer are presented in Figure 11.

![Figure 11. Representative ETa maps generated by the best state of parameterization of the SEBS related to 14/07/2010 (A) and 29/01/2010 (B)](image)

*Take-home message for decision-makers*

It is of vital importance to realize that the era of cheap water is over. The crucial outcome at this stage is to highlight the problems created by over-consumption of groundwater for crop
production, which are reversing the beneficial impacts of water-harvesting projects for groundwater recharge.

The failure to balance recharge versus extraction is the main reason for the receding water table countrywide.

Acknowledgment
This project was financially supported by the SUMAMAD project within the framework of Phase II activities for Iran. The Fras Research Center for Agriculture and Natural Resources provided the logistics and accommodation facilities at the Kowsar Research Station. Mr. Ali Fereidoonian, Mr. Gholamali Nekooian and Mr. Amir Arkia contributed extensively to the fieldwork. The author appreciates the intellectual and physical support of his colleagues in making the preparation of this progress report possible.

Publications in 2011

6.2 Monitoring of range and forest plants biodiversity of Gareh Bygone Plain in Fars province, Iran
Sayyed Hamid Mesbah, Fars Research Center for Agriculture and Natural Resources, Shiraz, Iran

Desertification annually puts millions of hectares of economically important ecosystems out of production. Desertification control through spate irrigation (SI) is a sustainable method for the management of marginal dry lands.

This study was implemented at the Kowsar Floodwater Spreading and Aquifer Management Research, Training and Extension Station, in the GBP, I.R. Iran, from May 2010 through September 2010. The GBP lies between latitudes 28°35’ and 28°41’ N and longitudes 53° 53’ and 53° 57’ E. Elevation of the study site varies from 1,120 to 1,160 m above the mean sea level (Figure 11). The GBP is an extremely dry place with a mean annual precipitation of 246.5 mm and Class A pan evaporation of 3,200 mm.

Temporal and spatial variations of precipitation in this plain are very high. Although the climate follows the Mediterranean regime, flood-producing thunderstorms may occur at any time of the year. The mean annual temperature is 19 °C, and the absolute minimum and maximum temperatures are -7 °C (January) and 43 °C (July). A structureless sandy loam (coarse-loamy skeletal, carbonatic (hyper) thermic, Typic Haplocalcids) (Soil Survey Staff, 1999), with average sand, silt and clay contents of 73.2%, 14.5% and 12.2%, respectively, form the 10-20 cm thick A horizon. The stony C horizon lies directly under the A horizon. More details on the site are presented elsewhere (Kowsar, 1991, 1998, 2008; Mesbah and Kowsar, 2010).

The presence, population density, crown cover and yield of the plants were determined in the BZ1 and BZ4 artificial recharge of groundwater (ARG) systems (treated), and on an area not receiving floodwater (control) on ten 1m² temporary plots established at random and on 150 m transects (Fig.12). Identification and measurements were performed yearly from May 2010 through September 2011 of all the plant species, irrespective of palatability. The sampling method was random – systematic method. The percentage of area covered by grasses, forbs, shrubs and litter, gravel and bare soil was determined using a 1m² frame with a 10 x 10 grid. All grasses and forbs in the 30 plots were clipped to 1cm height and air-dried to attain a constant weight. The current year growth of shrubs were also sheared and dried as before. The breast height diameter and height of 240 Eucalyptus camaldulensis Dehnh trees were measured using a Suunto Meter and callipers in the BZ1 and BZ4 ARG systems and control site. The means of population density, yield, crown cover percentage, and presence or absence of plant species in the ARG systems and control plots are presented in Tables 4 to 6.
Figure 12. Map illustrating the study area of the GBP, Islamic Republic of Iran

Figure 13. Plants species identification in spate irrigation (SI) and control sites. © Hamid Mesbah, FRCANR, Iran, 2011.
Table 4. Mean yield (kg/ha) in 2011

<table>
<thead>
<tr>
<th>Site</th>
<th>Shrubs</th>
<th>Forbs</th>
<th>Grasses</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>SI (BZ1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>28</td>
<td>87.3</td>
<td>235.5</td>
<td>350.8</td>
</tr>
<tr>
<td>2</td>
<td>14.1</td>
<td>64.8</td>
<td>130.6</td>
<td>209.5</td>
</tr>
<tr>
<td>3</td>
<td>74.9</td>
<td>63.8</td>
<td>73.3</td>
<td>212.0</td>
</tr>
<tr>
<td>4</td>
<td>8.7</td>
<td>128.4</td>
<td>30.0</td>
<td>168.1</td>
</tr>
<tr>
<td>5</td>
<td>42.1</td>
<td>112.1</td>
<td>38.1</td>
<td>192.3</td>
</tr>
<tr>
<td>6</td>
<td>69.3</td>
<td>171.8</td>
<td>3.1</td>
<td>244.2</td>
</tr>
<tr>
<td>Mean</td>
<td>39.52</td>
<td>104.7</td>
<td>45.86</td>
<td>229.5</td>
</tr>
<tr>
<td>SI (BZ4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.0</td>
<td>133.1</td>
<td>119.2</td>
<td>252.3</td>
</tr>
<tr>
<td>2</td>
<td>0.0</td>
<td>83.3</td>
<td>64.1</td>
<td>147.4</td>
</tr>
<tr>
<td>3</td>
<td>0.0</td>
<td>70.1</td>
<td>83.3</td>
<td>236.4</td>
</tr>
<tr>
<td>Mean</td>
<td>0.0</td>
<td>95.5</td>
<td>88.87</td>
<td>212.03</td>
</tr>
<tr>
<td>Control</td>
<td>38.4</td>
<td>116.4</td>
<td>3.1</td>
<td>157.9</td>
</tr>
</tbody>
</table>

Table 5. Mean soil cover of the flooded area and control site in 2011

<table>
<thead>
<tr>
<th>Site</th>
<th>Cover plant %</th>
<th>Litter %</th>
<th>Gravel %</th>
<th>Bare soil %</th>
</tr>
</thead>
<tbody>
<tr>
<td>SI (BZ1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>24.30</td>
<td>12.40</td>
<td>0.00</td>
<td>63.30</td>
</tr>
<tr>
<td>2</td>
<td>31.10</td>
<td>22.30</td>
<td>0.00</td>
<td>46.60</td>
</tr>
<tr>
<td>3</td>
<td>29.78</td>
<td>26.80</td>
<td>0.00</td>
<td>43.42</td>
</tr>
<tr>
<td>4</td>
<td>25.11</td>
<td>25.70</td>
<td>0.24</td>
<td>48.95</td>
</tr>
<tr>
<td>5</td>
<td>26.60</td>
<td>11.10</td>
<td>0.42</td>
<td>61.88</td>
</tr>
<tr>
<td>6</td>
<td>24.05</td>
<td>6.10</td>
<td>0.17</td>
<td>69.70</td>
</tr>
<tr>
<td>Mean</td>
<td>26.82</td>
<td>17.40</td>
<td>0.14</td>
<td>55.64</td>
</tr>
<tr>
<td>SI (BZ4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>14.73</td>
<td>50.70</td>
<td>0.00</td>
<td>34.57</td>
</tr>
<tr>
<td>2</td>
<td>10.11</td>
<td>78.65</td>
<td>0.00</td>
<td>11.24</td>
</tr>
<tr>
<td>3</td>
<td>21.85</td>
<td>17.3</td>
<td>0.00</td>
<td>60.85</td>
</tr>
<tr>
<td>Mean</td>
<td>15.56</td>
<td>48.88</td>
<td>0.00</td>
<td>35.55</td>
</tr>
<tr>
<td>Control</td>
<td>21.3</td>
<td>1.3</td>
<td>0.14</td>
<td>71.2</td>
</tr>
</tbody>
</table>

Table 6. Height and diameter of trees in control plot and floodwater spreaders in 2011

<table>
<thead>
<tr>
<th>Area</th>
<th>Site</th>
<th>Height (m)</th>
<th>Diameter (cm)</th>
<th>Clean bole</th>
<th>Tree</th>
<th>Breast height</th>
<th>Collar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Clean bole</td>
<td></td>
<td>Tree</td>
<td>Breast height</td>
<td>Collar</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Min</td>
<td>Max</td>
<td>Mean</td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>SI (BZ1)</td>
<td>2</td>
<td>3.15</td>
<td>7.50</td>
<td>0.80</td>
<td>7.90</td>
<td>13.80</td>
<td>4.60</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>2.81</td>
<td>6.00</td>
<td>0.50</td>
<td>7.87</td>
<td>14.70</td>
<td>2.30</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>2.60</td>
<td>4.90</td>
<td>1.30</td>
<td>2.3</td>
<td>13.80</td>
<td>3.30</td>
</tr>
<tr>
<td>SI (BZ4)</td>
<td>1</td>
<td>7.65</td>
<td>14.00</td>
<td>1.50</td>
<td>16.32</td>
<td>22.00</td>
<td>7.00</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>6.58</td>
<td>10.00</td>
<td>2.00</td>
<td>10.88</td>
<td>14.60</td>
<td>4.40</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>6.27</td>
<td>10.20</td>
<td>0.80</td>
<td>11.47</td>
<td>17.20</td>
<td>2.80</td>
</tr>
<tr>
<td>Control</td>
<td>5.20</td>
<td>10.00</td>
<td>1.20</td>
<td>10.10</td>
<td>16.00</td>
<td>4.00</td>
<td>40.18</td>
</tr>
</tbody>
</table>
Practical Implications
Spate irrigation is a low-input technology (Van Steenbergen et al., 2010), which may be implemented by the unskilled desert-dwellers with a minimum of training. Sedimentation of the suspended load improves the quality, thus productivity of the sandy soils. Moreover, artificial recharge of groundwater is an added benefit of spate irrigation where potential aquifers underlie the command area.

As spate irrigation of rangeland in Iran is a multipurpose endeavour, selection and propagation of plant species should be viewed from different angles. The list of plants helps range managers and animal nutritionists to decide which plants to select for application of the spate irrigation technique to improve sandy rangeland.

Acknowledgments
This study is a part of an ongoing project supported by the Fars Research Center for Agriculture and Natural Resources. The cooperation of Mr. Mansour Niazi Ardekani in the field work is gratefully acknowledged.

6.3 The effect of spate irrigation on the performance of jojoba (Simmondsia chinensis) in the Gareh Bygone Plain
Sayyd Morteza Mortazavi, Fars Research Centre for Agriculture and Natural Resources

Project activities
Simmondsia chinensis (Link) Schneider, commonly known as jojoba, is a dioecious evergreen shrub native to dry regions of the southwest United States of America and northern Mexico. This species is very tolerant of drought and heat and is of great importance in terms of soil conservation and combating desertification. Moreover, it produces seeds containing about 40% to 60% liquid wax, a unique substance of great value in cosmetics, food, pharmaceuticals and other industries.

Water scarcity has pushed the inhabitants of the Gareh Bygone Plain to abandon high water demand agricultural products, and even to leave the region to migrate to cities with little or no employment opportunities thereby only worsening their dismal situation.

As Jojoba is a low water demand species, it is assumed to have the potential to generate future income for the plain dwellers and inhabitants. The performance and adaptation of this species south of Fars province has been previously studied under rainfed and irrigated conditions. Suitable sites were selected in the Gareh Bygone Plain in February 2007. The site comprised of two adjacent locations: high ground with rainfed treatment (control) and low ground, which might be potentially irrigated with a meagre amount of floodwater. In late February 2007, the two-year-old potted jojoba seedlings were planted. All plants were irrigated once every 15 days in the dry season of the first year to aid help their establishment. Growth, mortality and phenological factors, including flowering, sex differentiation and so on, of the plants, were monitored on several occasions each year.
Preliminary results obtained
Growth assessments (seedling height, number of stems, crown diameter, etc.) were carried out in the late summer of 2011. Plants in the control plot had suitable conditions and were growing well with 12 plants producing flowers and seeds (Figure 13). The mean height of the control plants measured in September 2011 was 84 cm. The plants in the low area did not perform well, and most died in spite of receiving some floodwater several times during 2009 and 2011. This strange result may be due to water logging and shows that this species does not tolerate such conditions. The lost seedlings in the severe drought of the year 2010 were replaced in March 2011.

Preliminary recommendation to decision-makers
In general, Jojoba demonstrated acceptable adaptation to the GBP in terms of growth performance in almost rainfed conditions. The jojoba seedlings have reached the stage of seed production.

The growth of rainfed plants was not as satisfactory as expected due to severe climatic factors including exceptional high temperatures as well as very low annual rainfalls during the last four years. However, the final analyses and assessments will be made after four years.

It is too early to recommend any commercial plantations until more extensive experiments have been carried out in the context of comparison between provenances and clones, especially under several edaphic conditions. Different provenances and ecotypes of jojoba must be introduced and selected to ascertain those most suitable.

It must be noted that the expenses of the remaining two years of field and laboratory works (taking new soil samples, soil analysis, weed control, growth assessments and travel expenses, etc.) amount to more than USD 2,200 for each year due to the removal of subsides, as well as the growing rate of inflation in Iran.
6.4 Alternative income-generating activities in Gareh Bygone Plain
Gholamreza Chabokrow, Shahrokh Shajari and Representatives of Cooperatives, Fars Research Center for Agriculture and Natural Resources & REaSSURED

Project activities in 2011
The present project is important in assessing the employment opportunities that exist for farmers in drought-prone areas such as the Gareh Bygone Plain. The main goal of this project is to produce an economic evaluation of alternative activities that can generate income for small farmers, especially in drought conditions, so as to prevent migration and negative impacts on natural resources, and to increase employment opportunities and welfare in rural areas.

Based on the methodology used in this study, the participation of local groups within a people-oriented approach is crucial to sustainable development. In fact, participatory decision-making and sharing in responsibilities are the most important elements of true participation.

Certain instruments are needed to develop such participation, including organizing, institutionalizing and appropriate structural conditions. Only if these conditions materialize will proper participation take place. Participatory Rural Appraisal (PRA) and Rapid Rural Appraisal (RRA) are two methods that have been used during the past decade to study the life of villagers, and bring them into play at different levels of rural development. Participatory rural appraisal is a learning method that helps villagers to recognize, analyse and evaluate their limitations and opportunities, as well as to raise awareness and make decisions during development projects. According to this method, the villagers are the innovators and have the ability to recognize and analyse the challenges they are confronted with.

The suggested development projects were evaluated using economic methods such as benefit-cost ratios, and Internal Rate of Return (IRR).

Preliminary results obtained
Using the research methods, the needs and challenges of the villagers were identified during the first stage. Some of the outcomes are indicated below. The final results of the study, based
on the findings of the questionnaires and the benefit–cost methodology, are being processed and will be presented during the final stage of the study.

*Population growth rate*
The average population growth rate in the villages of the study area over the decade 1986–96 was low (0.28%), while the rate in the subsequent decade 1996–2006 even turned negative (-0.25%). Compared with the average population growth rate of rural areas in Iran, (Fars province and the city of Fasa) the results indicated that out-migration from the study area towards urban environments or other districts was taking place.

*Occupation*
To analyse this indicator, information was collected on the number of employed people per household (or who had a second job) as well as the type of employment. The results of the study indicated that in 81% of the households surveyed, only the head of the household was employed. Agriculture is the main activity in the study area; however, the eight villages surveyed showed different levels of engagement in agricultural activities.

*Household wealth ranking*
Based on the results of the household questionnaires, the wealth ranking of the households in the study area was determined as average, poor or very poor level. No household enjoyed a good level of welfare. Results indicated that greater vulnerability reflects, the higher levels of poverty in the study area.

*Migration*
During the last decade, information gathered from key informants indicated that migration to cities and other rural areas occurred in 75% of villages. Unemployment and out-migration are the two main results of groundwater recession and degradation.

*Participation in social networks for common goals*
Participation in social networks, such as local organizations, production cooperatives and microfinance funding, may be considered as a way to cope with crises brought about by drought and groundwater degradation. The results show low participation of rural households in social networks due to low awareness and a lack of belief about collective activities, and therefore, a low likelihood of coping with emergency situations.

*Benefit-cost analysis*
The suggested projects were evaluated using economic methods such as benefit–cost ratios, and Internal Rate of Return (IRR). The necessary data were collected and analysed. The final results of the study, based on the findings of the benefit–cost methodology to introduce selected jobs to the area are being processed and will be presented at the final report.

Some of the limitations and constraints of the study area:
- Freshwater shortages
- Water shortages for agricultural activities
- High unemployment rate
- Lack of industrial activities
• Lack of bank credits
• Lack of paved farm roads
• Shortages of sport and training facilities
• Lack of agricultural commodities cooperatives
• Inadequate facilities and services

Figure 15. Participatory Rural Appraisal (PRA) and Rapid Rural Appraisal (RRA) in the GBP
6.5 Feasibility of producing organic honey from the Kowsar floodwater spreading system in Gareh Bygone Plain
Bahman Eilami, Fars Research Center for Agriculture and Natural Resources

Water scarcity was the main reason why the inhabitants of Gareh Bygone Plain gave up agriculture and migrated from this region to cities with little or no employment opportunities. Beekeeping and the production of honey, however, is one way by which inhabitants of this region can generate income.

The Kowsar Floodwater Spreading Research Station has been established downstream of a 192 km² basin in a sandy desert in the Gareh Bygone Plain, southwest Iran. Following 26 years of FWS activities, an artificial ecosystem has been created and soil properties, particularly water retention characteristics and vegetation cover, have significantly improved. Certain species of Acacia and Eucalyptus trees were planted at the station, as Eucalyptus camaldulensis, E. microtheca, E. gillii, E. intertexta, E. oleosa and Acacia victoriae, and A. salicina can adapt to the environmental conditions of the plain. These trees flower sporadically all year round; therefore, enough nectar and pollen are available for honeybees throughout the year.

Honey used for nutritional purposes should be harvested in areas without contaminated sources. Concerns about traces of numerous toxic substances have prompted a great demand for honey certified as organic. Organic honey production is an ecologically based system, which encourages the use of good agricultural practices to maintain the agricultural ecosystem balance and diversity, promoting the sustainable use of natural resources, environmental quality, animal welfare and human health. Research results indicate that the botanic origin of honey, different beehive types, and the material that beehives are made of, all have an influence on the quality of the honey.

In order for honey to be certified organic, the beehives must be placed in isolated areas miles from the dense population, industry, traffic congestion and farm fields treated with chemicals and landfills. In addition, a bee’s flying range is determined by their natural instinct, which tells them to stay within their natural four-mile range from the hive location. Finding an area that can be certified as organic is difficult, which is why there is so little certified organic honey on the market. These regions are a rich source of wild vegetation that produce some of the finest honey in the world. The USDA and Canadian Organic Certification impose a rigorous set of standards and conditions that must be adhered to by both the producer (beekeeper) and the packager. All aspects of honey production, including the source of the nectar, the forage area of the bees, management of the bees, the extracting process, and transportation are taken into account in the certification process.

The main objective of this study was to produce organic honey in a Eucalyptus plantation in the Gareh Bygone Plain. At the beginning of February 2010, 20 honeybee (Apis mellifera L.) colonies were bought, standardized and reared under specific care. The bees were not fed sugar syrup and did not receive any synthetic chemical substances. The honey contained in the beehives was completely extracted. At that time, some species of acacia and eucalyptus were in flower. The colonies foraged on the nectar and pollen from February until early April. The two-month yield was removed from the beehives on 1 April 2010 and the queen excluders were placed on the top of the beehives. A shallow super (additional tray) was placed over the queen excluder to collect the extra honey. The dominant plant at the project site was E. camaldulensis, and the best foraging took place during May and June, when this tree was in flower. Honey samples for chemical analysis were collected at the end of May.
Physico-chemical analyses

Physico-chemical analyses of the honey samples were performed in accordance with the Official Methods of Analysis of Association. The evaluated parameters were: water content, hydroxymethyl-furfural content (HMF), free acidity, diastase activity, reducing sugars, saccharose and pH.

Analyses for metal concentrations:
Metal concentrations in different honey types depend largely on the elemental composition of flowers with regard to their botanical and geographical origin. Previous studies have suggested that honey may be useful as an environmental indicator of heavy metal pollution (As, Cd, Pb, Hg), as honeybees may be continuously exposed to contaminants present in an area of approximately 7 km² surrounding the apiary. The presence of metals may be caused by external sources such as industrial smelter pollution, emissions from factories, non-ferrous metallurgy, leaded petrol from busy highways, incorrect procedures during the honey processing and conservation phases, and agrochemicals such as cadmium-containing fertilizers, organic mercury, and arsenic-based pesticides still in use in some countries. The analyses for arsenic (As), cadmium (Cd), copper (Cu) and lead (Pb) were conducted by graphite furnace atomic absorption. Some honey samples were collected and sent to a reference lab for metal concentration detection. The results will be presented in the final SUMAMAD-2 report for Iran.

Table 7: Chemical analysis of Fars Eucalyptus honeys samples.

<table>
<thead>
<tr>
<th>Moisture (%)</th>
<th>HMF</th>
<th>pH</th>
<th>Total acidity (Meg/kg)</th>
<th>Diastase activity</th>
<th>Deviation of light</th>
<th>Reducing sugars (%)</th>
<th>Saccharose (%)</th>
<th>Commercial glucose</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.4</td>
<td>Negative</td>
<td>3.76</td>
<td>27.1</td>
<td>Positive</td>
<td>-4</td>
<td>78.3</td>
<td>4.42</td>
<td>Negative</td>
</tr>
</tbody>
</table>

The maximum amount of water present in pure floral honey is not more than 20% in general. Knowledge of the moisture in honey is useful to improve its conservation and storage. The water content of honey depends on various factors, for example, the harvesting season, the degree of maturity reached in the hive and environmental factors. HMF and diastase activity are parameters widely recognized for the evaluation of honey freshness and/or overheating. No sample exceeded the limits established for these variables by international regulations. Values obtained for HMF and diastase activity are typical of unprocessed honey. The low pH of honey inhibits the presence and growth of micro-organisms and makes honey compatible with many food products in terms of pH and acidity. This parameter is of great importance during the extraction and storage of honey as it influences the texture, stability and shelf life of honey. The acidity of honey may be explained by taking into account the presence of organic acids in equilibrium with their corresponding lactones, or internal esters, and some inorganic ions, such as phosphate. All of the samples investigated met the demands set out in the regulations. Honey is mainly composed of the monosaccharides glucose and fructose. The saccharose content of the honey must be under 5%, and those analysed fell within this range.
6.6 Empowering local organizations to participate in aquifer management in the Gareh Bygone Plain
J. Zabetian and M. Majedi
Fars Research Center for Agriculture and Natural Resources

The socio-economic behaviour and future outlook of Iranians in rural areas has been altered by the recurrent and severe droughts of the past five years, water scarcity for agricultural activities, the removal of subsides, and an accelerating inflation rate. In spite of the establishment of local cooperatives in the study area in 2008, members are hesitant to invest in or contribute to the new activities. Although they are encouraged to participate in water-harvesting project in the undulating areas of the GBP, they are in doubt of receiving government funds to support their investment. As a matter of fact, most rural people in Iran are now in heavy debt to the banking system and are afraid to start any new venture. These are the main reasons for the failure of efforts to encourage local cooperatives to participate in the AQUITOPIA project in 2011.

6.7 Effects of the Sowbug (Hemilepistus shirazi Schuttz) on desertification control
Gholamreza Rahbar
Fars Research Center for Agriculture and Natural Resources

Project activities
The appearance of sowbugs (Hemilepistus shirazi Schuttz) (Figure 15) in the sedimentation basins of the artificial recharge of groundwater (ARG) systems in the Gareh Bygone Plain (GBP) in southern Iran is considered an ecological breakthrough in desertification control. Sand dunes occupy about 12 million ha of land of Iran, and significantly more in other countries.

Stabilization of these expanses with environmentally friendly materials and methods is of the utmost importance. Moreover, the construction of dwellings and infrastructures in such environments at very low cost is a challenge facing engineers. The importance of fauna as indicators of soil quality must be assessed in terms of the specific functions they are expected to perform (Larson and Pierce, 1994). The main function expected of this creature is puncturing the hard crust, facilitating rapid percolation of recharge water. Therefore, the presence of sowbugs may be considered a valuable indicator of land suitability for ARG activities. However, as this fauna was a welcome addition to the research site it was hypothesized that it could start a completely new life cycle in the area. The excavated soil had more organic matter and a better structure, thus was more resistant to erosion than the original soil from which it was extracted (Saleh-Rasteen, 1978). A serendipitous discovery that the lining of the burrows prevented the collapse of fine sand encouraged the study of numerous different aspects of the sowbugs’ life. It was reasoned that the body fluid, which dries instantly and forms a strong tube that functions as the entrance to the sowbugs’ semi-spherical, 5 cm to 10 cm in diameter nests, affects the composition of the parallelepiped-shaped burrowed material. This was revealed by chemical analysis. The objective of this study was to characterize the lining of sowbug tunnels. The lining material of sowbug is environmentally safe, and if synthesized, revolutionizes desert construction industries and sand dune stabilization activities. The higher levels of organic carbon in the burrowed material, as compared with those of the original soil and the freshly-laid sediment, represent a potential for carbon sequestration when viewed as a long-term management system.
During 2010 and early 2011, the main activity focused on determining of the lining tunnel composition of the sowbug. The first steps were collection of suitable samples and laboratory analysis of the lining tunnels.

Figure 16. A dorsal view of a female *Hemilepistus shirazi Schuttz.* © Gholamreza Rahbar

The BZ1 system in the recharge area was selected in order to characterize some of the physico-chemical properties of the sowbug burrowed materials. The system on which this study was conducted was the first in a series of eight systems constructed in the Gareh Bygone Plain since 1983. This system comprises six sedimentation basins the second of which has the largest sowbug population. About 2 kg of the rod-shaped soil (burrowed material) were collected from 70 sowbug-infested plots (10 g – 20 g adjacent to each opening).

Samples were thoroughly mixed. The same amount of surface soil (freshly laid sediment) was also taken from the adjacent plot without the burrows, as a control. This sample was thoroughly mixed too. Particle size distribution (sand, silt and clay), saturation percentage, EC, pH, bicarbonate, carbonate, cation exchange capacity (CEC), organic carbon, potassium, phosphorus, total nitrogen, iron, copper, magnesium, zinc, and the dissolved cation and anion were determined using the standard procedures.

**Preliminary results obtained**

A chi-square test was used to compare the physico-chemical properties of the burrowed materials and the freshly laid sediment (control):

\[
\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i}
\]

Where \( O_i = \text{Sowbug}, \ E_i = \text{Without Sowbug (Check)} \)

\[
\chi^2 = 111.446 \ **
\]

\[
\chi^2(\%5,10) = 18.307 \quad \chi^2(\%1,10) = 23.209
\]

According to obtained amounts and degrees of freedom (K-1), the value of \( \chi^2 \) was calculated and compared with the chi-square distribution table (Table 8).
Table 8. Chi-square distribution and significant level table for sowbug burrowed materials

<table>
<thead>
<tr>
<th>Variable</th>
<th>$\chi^2$</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>%sand</td>
<td>37.79</td>
<td>0.000</td>
</tr>
<tr>
<td>%silt</td>
<td>399.55</td>
<td>0.000</td>
</tr>
<tr>
<td>%clay</td>
<td>61.28</td>
<td>0.000</td>
</tr>
<tr>
<td>water satu.per.</td>
<td>209.56</td>
<td>0.000</td>
</tr>
<tr>
<td>pH</td>
<td>1.81</td>
<td>0.874</td>
</tr>
<tr>
<td>EC</td>
<td>70.07</td>
<td>0.000</td>
</tr>
<tr>
<td>%O.C.</td>
<td>404.30</td>
<td>0.000</td>
</tr>
<tr>
<td>Ava. K</td>
<td>112169.23</td>
<td>0.000</td>
</tr>
<tr>
<td>Ava. P</td>
<td>738.06</td>
<td>0.000</td>
</tr>
<tr>
<td>%T.N.</td>
<td>37.34</td>
<td>0.000</td>
</tr>
<tr>
<td>%CCE</td>
<td>1.26</td>
<td>0.939</td>
</tr>
<tr>
<td>Fe</td>
<td>92.91</td>
<td>0.000</td>
</tr>
<tr>
<td>Zn</td>
<td>29.92</td>
<td>0.000</td>
</tr>
<tr>
<td>Cu</td>
<td>925.80</td>
<td>0.000</td>
</tr>
<tr>
<td>Mn</td>
<td>5757.53</td>
<td>0.000</td>
</tr>
<tr>
<td>K$^+$</td>
<td>90.18</td>
<td>0.000</td>
</tr>
<tr>
<td>Na$^+$</td>
<td>678.75</td>
<td>0.000</td>
</tr>
<tr>
<td>Mg$^{2+}$</td>
<td>1146.59</td>
<td>0.000</td>
</tr>
<tr>
<td>Ca$^{2+}$</td>
<td>632.83</td>
<td>0.000</td>
</tr>
<tr>
<td>Cl$^-$</td>
<td>1540.95</td>
<td>0.000</td>
</tr>
<tr>
<td>SO$_4^{2-}$</td>
<td>263.25</td>
<td>0.000</td>
</tr>
<tr>
<td>HCO$_3^-$</td>
<td>786.31</td>
<td>0.000</td>
</tr>
<tr>
<td>CO$_3^{2-}$</td>
<td>1.20</td>
<td>0.945</td>
</tr>
<tr>
<td>CEC</td>
<td>34.73</td>
<td>0.000</td>
</tr>
</tbody>
</table>

$\chi^2_{(0.05,5)} = 11.07$  \hspace{1cm}  $\chi^2_{(0.01,5)} = 15.09$
According to Table 8, with the exception of pH and calcium carbonate, all other items show significant differences (p<1%) between the sowbugs’ burrowed materials and the control, implying effective physico-chemical alterations caused by the sowbugs’ internal digestion system.

**Preliminary recommendation to decision-makers**

This crustacean (sowbug) improves the physico-chemical properties of soil, and as such is important and useful for enhancing water infiltration into the soils of sedimentation basins of floodwater spreading systems. Sowbug activity is beneficial for improving soil physical conditions and thus, plant growth. Burrowing by the sowbug improves air and water penetration into the soil. The burrowed materials and castings resist erosion more than the freshly laid sediment from which they are formed. Sowbug activity also improves the chemical properties of soil and makes it more fertile. They increase soil organic carbon content which plays a key role in soil productivity and environmental quality.

7. **National workshop**

**Introduction**

The Third National Workshop on the Sustainable Management of Marginal Drylands SUMAMAD-2, Iran’s Case Study was held at the Kowsar Research Station, Gareh Bygone Plain, Fasa on 31 October 2011. The Research Society for Sustainable Rehabilitation of Drylands (REaSSURED) organized the workshop in corporation with the Fars Research Center for Agriculture and Natural Resources.

**Objectives**

The main objectives of the Workshop were: (a) to review the achievements of the SUMAMAD-2 ongoing sub-projects in the study area; (b) to present scientific papers related to the drylands of Iran (drought, management of drylands, groundwater degradation, human security, social and economic impacts of drylands, climate change and desertification control); and (c) to visit the projects in the Gareh-Bygone Plain and discuss their common issues.

**Summary of the Workshop**

Dr. Maftoun Azad, Deputy for Research of Fars Research Center for Agriculture and Natural Resources welcomed the participants from the REaSSURED, the Fars Research Center, Shiraz University, local governmental authorities, representatives of local cooperatives and local people to the workshop, and presented opening remarks together with Dr. Chabokrow from REaSSURED. Mr. Mesbah presented the objectives and the overall framework and structure of the SUMAMAD project in Iran. The next part of the workshop resumed with a lecture presented by Mr. Safarpour, Governor of Shibkouh District. The main part of the workshop continued with presentations and discussions on SUMAMAD and other related projects by the project leaders regarding the achievements in 2011. Workshop presentations continued with a brainstorming session in which the participants draw conclusions on different aspects and advantages of floodwater spreading systems, and the outlook for their improvement. A short field visit was also arranged to the floodwater spreading systems including activities related to the SUMAMAD sub-projects in the second part of the workshop.
Titles of the Iran National Workshop presentations (2011)

Barkhordari, J. and Mirjalili, A. Effects of floodwater spreading on the vegetative cover of aquifer in drought and wet periods.
Barkhordari, J. Effects of floodwater quality on range biodiversity in Sarchahan city.
Fatehi, A. Impacts of drought periods on floodwater spreading system management.
Ghafouri, M, and Sarreshtedari, A. Social interaction and cooperation in aquifer management projects; new prospective in aquifer management.
Kadkhoda pour, M.A. Impacts of floodwater spreading system on soil infiltration properties of the Harat Station.
Mirjalili, A. Urban landscape development using unusual brackish water resources.
Moghim, H. Development necessity, construction conditions and positioning of underground dams in Fars Province using GIS.
Mollaee, M.Taghvaei, Y. Erfanifard and Safaeyan, R. A non-destructive method to predict above-ground biomass of perennial range species by modeling in the arid semi-arid ecosystems.
Rahimi Zaji, A. and Mirjalili, A. Soil and water resources management through floodwater spreading system implementation.
Sarreshtehdari, A and Ghafouri, M. Social interactions and community participation in floodwater spreading projects: third generation in watershed management.
Zaremehrjardi, M. and Barkhordarior, J. Effects of floodwater spreading on reclamation of soil texture of Sarchahan Floodwater Spreading areas, Hormozgan province.
8. References


