SUSTAINABLE DRYLAND LANDSCAPES MANAGEMENT

MAPPING RANGELAND IN JORDAN 2015

Legend

Forage DM (kg/ha)
- 182
- 220
- 346
- 478

Management
- Tribal/Open grazing
- Tribal/Open grazing
- Governmental/Range Reserve
- Communal/Hima

INTERNATIONAL UNION FOR CONSERVATION OF NATURE – REGIONAL OFFICE FOR WEST ASIA

MINISTRY OF FOREIGN AFFAIRS OF DENMARK
DANIDA
INTERNATIONAL DEVELOPMENT COOPERATION
Acknowledgements

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“The contents of this publication are the sole responsibility of the International Union for Conservation of Nature.”
1 Summary

Within the efforts of the IUCN, physical characterization was carried out for rangelands of Jordan to select areas or sites with high potential for investment and development as rangelands through sustainable community-based approach and involvement of key stakeholders. The work of characterization provided the first step needed for developing a policy document which would be translated into an investment plan. The procedure for selection was based on physical characteristics and constraints on the form of exclusion decisions. The selection was refined following discussions with experts from governmental institutions and the opinions of rangeland experts following field visits to the initially selected areas and watershed. Characterization was carried out for watersheds and subwatersheds that were delineated by GIS using a medium resolution digital elevation model (DEM). The different maps of vegetation zones, land use, soil, land tenure and water harvesting were either generated or provided by the GIS expert or through data exchange with governmental and nongovernmental organizations.

The approach of selection was based on excluding areas with physical limitations (rainfall, soil, land tenure, vegetation and topography) that would make rangeland development non-feasible. Initial results showed that there are 16 watersheds (constitute 23% of the country’s area) where rangeland development can be scaled up at watershed level. The selected watersheds were representing different ecosystems and vegetation types, with most being in Hammada ecosystems. Therefore, selection was expanded to include other biogeographic zones with different vegetation types. Analysis of remotely sensed data was carried out for the MODIS-NDVI data with 250m spatial resolution and 16-day temporal resolution. The data of NDVI indicated that there were potential sites in different ecological zones in Jordan.

Following meetings and discussions with rangeland experts and the field visits, four sites were selected as areas with high potential to start the plan of investment in rangeland. These were located south of Kharraneh to Ash-Shomari Reserve, Ayra-Yarqa Reserve on Jordan Rift Valley, Hima Bani Hashim west of Zarqa and Al-Husseiniyah to the north of Ma’an. The other possible sites were mainly in the eastern arid zone (Badia) within the selected watersheds. Part of these watersheds and subwatersheds were under investigation by the Badia Restoration Program and other institutions. For this project, the four sites were seen as locations with high potential for development that could be scaled up for the selected watersheds.
2 Introduction

Development of rangelands requires assessment and evaluation of available biophysical and human resources in these fragile landscapes. Assessing rangeland for restoration and development includes the use of both quantitative and qualitative indicators to evaluate the current status of land resources. Soil and vegetation parameters are considered the most important physical indicators for rangeland assessment as they can indicate ecosystem health and resilience level.

In Jordan, rangelands are usually defined as the areas that receive less than 200 mm of annual rainfall. As such, they cover more than 90% of the country’s lands (Figure 1). Although many studies and research tackled rangelands resources in Jordan, however, many misleading figures were reported on the areas of rangelands and their contribution to livestock production. Considering the frequent droughts and overgrazing of natural vegetation, the levels of rangelands degradation in Jordan are expected to be high. Regardless of their contribution to livestock production, rangelands in the arid and arid areas include important ecosystems that contribute to Jordan’s biodiversity. Also, they host more than 300 villages and towns were many communities are living and use the fragile rangeland resources. Therefore, community-based rangeland management approaches could be feasible to conserve the important plant and animal resources.

This report forms part of the IUCN project entitled “Sustainable Dryland Landscapes: Closing the Knowledge-Policy Implementation”. The overall aim of the project is to inform national governments to invest in rangelands/pastoral communities to support practices that are environmentally and economically sustainable. The approach of the project is based on developing a policy document for adoption by decision-makers so that an investment plan will be developed with all components of action plan and financial channels. This report provides GIS analysis of data and information on the available rangelands resources, vegetation zones and ecosystems, surface hydrology and vegetation conditions derived from remote sensing data. Two meetings with stakeholders and rangeland experts were held to deliver initial results and to refine the selection of four sites that could be recommended for rangeland investment that can be scaled up to other parts of the country. The selected sites were visited to identify locations were rangeland development could start as initiative for scaling up the plan for the selected watersheds, after identification of needed capacities and plans for investment.
Figure 1: Rainfall distribution in Jordan (source: JMD)
3 Data collection and processing

Different data were collected and processed by the GIS expert to carry out initial selection of watersheds for rangeland development and pastoral investment. The following subsections describe the data and the processing carried out to refine the selection.

3.1 Satellite images

Medium resolution satellite images of Landsat 8 were downloaded from the official website (http://earthexplorer.usgs.gov/) of the data. The images of Landsat were processed for mapping irrigated areas in the arid and desert rangelands and to improve the land use/cover map of the country by adding more details for land use/cover classes of urban, quarries, wadis and sand dunes existing in the vegetation zone of Hammada. The layers of wadis and sandy Hammada were used to increase the details of vegetation map and to derive a map of Jordan rangeland ecosystems.

The second set of satellite images that was in this work was the high temporal resolution data of the Moderate Resolution Imaging Spectrometer (MODIS). The data of NDVI represented a maximum daily NDVI composited for every 16 days. The total number of images for each year was 23. The NDVI data with 250 m spatial resolution were downloaded from the web (https://wist.echo.nasa.gov/api/) for every 16 day during the last 10 years, the total number of images was 230. The data was then stacked in one image and processed to derive the map of the mean NDVI. Also, it was processed using the Principal Component Analysis (PCA) and the unsupervised classification to derive a map of the NDVI classes for the main vegetation zones in Jordan. The output layer was used to refine selection of watersheds to include different types of vegetation and different levels of productivity.

3.2 Digital Elevation Model (DEM) and Topographic maps

The data of the Shuttle Radar Topography Mission (SRTM) was downloaded on the form of DEM that has a resolution of 90m. Topographic maps at scales of 1:50000 and 250000 were used to refine the output (streams and watersheds) and to identify the main streams and wadis. The names for the final sub-watersheds were based on those reported in the topography maps.
3.3 Soil maps

Soil maps of Jordan were produced through the national soil map and land use project (NSMLUP) which was carried out by the Ministry of Agriculture (MoA) and other institutions and agencies during the period 1989-1995 (MoA, 1993; MoA 1995). The soils at the reconnaissance level with a scale of 1:250,000 covered the entire country (89,500 km$^2$). The GIS expert (Prof. Jawad Al-Bakri) was involved in digitizing and processing these maps within GIS at the University of Jordan. The general soil map (Figure 2) shows that most of rangelands are dominated by arid soils (cambids and calcids). The maps were also analyzed by the GIS expert to derive the spatial extent of gypsic and saline soils (Khresat et al., 2010) so that selection of watersheds would be refined by soil constraints.

![Main soil types of Jordan](Source: Ababsa, 2013)
3.4 Land use/cover map

An official accurate land use/cover of Jordan map for Jordan is not published yet. The best available map was prepared by the Royal Jordanian Geographic Center (RJGC) in year 2006, based on the use of digital classification of Landsat images. The map was published in the Atlas of Jordan (Ababsa, 2013). This map (Figure 3) was updated by Prof. Al-Bakri (GIS expert) who added more details to urban and irrigated areas in highlands and desert regions (Al-Bakri et al., 2013). The classification scheme of the map is very useful as it tells more about land cover and it shows that many of the country’s lands are covered by basalt and chert. Detailed analysis of land use/cover was made and data was summarized to identify the actual areas of rangelands in Jordan. Also, the map was used to add more details to the sandy areas in the Hammada ecosystem.

3.5 Vegetation map

Different small scale maps were produced for Jordan’s biogeographic and bioclimatic zones, which include four distinguished zones (Mediterranean, Irano-Turanian, Saharo-Arabian and Sudanian Penetration). The most detailed map for vegetation was produced by Albert et al. (2003) based on previous studies in Jordan (e.g. Al-Eisawi 1985 and 1996). The GIS expert prepared the map of vegetation in GIS format and added the class of sandy Hammada to the eastern parts from the land use/cover map and the NDVI images of MODIS.

3.6 Macro-catchment water harvesting projects

Hardcopy reports of macro-catchment water harvesting projects were obtained from the Ministry of Water and Irrigation (MWI), Ministry of Agriculture (MOA) and the Ministry of Environment – Badia Restoration Program BRP. The water harvesting projects mainly included small earth dams, known as Hafeer, and stocking ponds for livestock sector. The aim behind the use of this data was to identify sites with watering points for livestock and possibly for rangeland rehabilitation. These points were considered in selecting watersheds were development could be scaled up, as these macro-catchment structures were already established by MWI, MOA and BRP to serve grazing routes in different parts of the country. Locations of water harvesting projects were prepared in spreadsheets and transferred to GIS layers. Grazing routes were obtained from the RSCN and overlaid onto the watershed and watering points map. Selection was then made based on the existence of these watersheds on the grazing routes and the presences of watering points on these routes.
3.7 Cadastral map and socioeconomic data

These included land tenure map of the country, obtained from the Department of Land Survey (DLS) with small details on the form of boundaries for privately owned lands. The Department of Statistics provided the expert with figures of poverty on the form of report. A table was prepared and appended to the map of governorates and districts to prepare a general map of poverty. The map of poverty was based on the most recent survey, which was for year 2010. In this survey, poverty level was based on household expenditures and income (DOS, 2010).
4 Delineation of subwatersheds (catchments)

The DEM was used within GIS to derive two important layers: stream network and the main catchments (subwatersheds). The hydrology tools of ArcGIS were used for this purpose. The procedures followed to derive the two layers included filling of sinks within the DEM, calculating flow direction, generating the flow accumulation layer, reclassifying the flow accumulation layer to generate streams, drawing a layer of pour points at the intersection of streams and generating the layer of small watersheds (subwatersheds) using the layer of flow accumulation and the map of pour points. The final output map from this delineation process is shown in Figure 4.

The output from the delineation was refined using available topographic maps. The areas of depressions were excluded from the map. These areas included the depression of Sirhan, Azraq and Jafir. The map was edited to remove delineation errors and the intersections that resulted from this process. Subwatersheds that were located within the lands of Jordan Valley Authority (JVA) or in areas extending outside Jordan were removed from the map. The output from this delineation (Figure 4) resulted in a map with 445 subwatersheds, with an average catchment area of 155 km².
Figure 4: Stream network and the small watersheds (sub-watersheds), as derived from the SRTM DEM.
5 Watersheds selection and characterization

5.1 Initial selection of subwatersheds

Different GIS maps were used to select subwatersheds that included sites with high potential for rangeland development. This selection was based on primary parameters (mainly physical) of subwatersheds. The criteria for selection was based on the exclusion of unsuitable subwatersheds based on physical parameters of rainfall, soil and vegetation and the socioeconomic parameter of land tenure, as shown in Table 1. The selection will be refined after further investigation with the project’s rangeland expert and after merging socioeconomic data with GIS maps.

<table>
<thead>
<tr>
<th>Parameter(s)</th>
<th>Criteria for selection (inclusion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall</td>
<td>Inclusion of rangeland areas with mean annual of ≤ 200 mm</td>
</tr>
<tr>
<td>Land tenure</td>
<td>- Treasury land is preferred over privately owned land.</td>
</tr>
<tr>
<td></td>
<td>- Landholding size of 1.0 ha or more for privately owned lands.</td>
</tr>
<tr>
<td>Soil Limitations</td>
<td>Exclusion of areas with high salt contents, sand dunes, mudflats (depressions), high content of gypsum enriched soils.</td>
</tr>
<tr>
<td>Land Use/cover</td>
<td>Exclusion of Urbanized and irrigated areas and areas with industrial activities (quarries, excavation, oil and gas).</td>
</tr>
<tr>
<td>Accessibility and Infrastructure</td>
<td>Availability of roads (within 20 km from paved road and within 10 km of tracks) and watering points (within 20 km from hafeers).</td>
</tr>
<tr>
<td>Topography and vegetation</td>
<td>- Slope range is 1-6%, i.e. suitable for micro water harvesting needed for restoration (Only for Hammada ecosystem).</td>
</tr>
<tr>
<td></td>
<td>- Vegetation type is including either shrub or grass rangelands or both based on the NDVI class.</td>
</tr>
</tbody>
</table>

The steps followed for the selection are summarized as follows:

1. The criteria for rainfall and land tenure resulted in reducing the number of selected sites from 437 to 323 subwatersheds (Figure 5).
2. The maps of soils, in addition to vegetation, were used to exclude areas of sand dunes, mud flats, and saline soils. The output from this stage resulted in reducing the subwatersheds from 323 to 204, as shown in Figure 6.
3. The maps of land use/cover and Master land use plans use were used to exclude areas dominated by quarries and mineral extraction, industrial activities and irrigation. The area of Wadi Rum was excluded as it was planned for eco-tourism, while the area of Qasabat Ma’an was excluded due to its planned land use. These criteria refined the selection to 181 subwatersheds (Figure 7).
4. The network of roads and tracks and the map of watering points (Hafeer and earth dams) were used to exclude areas with no access in the initial stage and to include them later within the scaling up for watershed level. The components of this overlay, shown in Figure 8, refined the selection to 140 subwatersheds.

Figure 7: Map of subwatersheds after considering existing and planned land use.
5. The maps of Topography and vegetation index (NDVI range and class) were used to finalize the selection of subwatersheds. The slope criteria (<6%) and the vegetation index of <0.20 for rangeland classes reduced the number of watersheds to 69 (Figure 9).
The total selected subwatersheds were 69, located within 16 main watersheds (Figure 10). These were Al-Qasab, Abu Hifneh (Bandan), AlQatafi, Wadi Rajil and Al-Azraq in the northeast, Zarqa, Al-Oayned, Shaumari, Ad-Dabei and Al-Ghadaf in the middle and Waqa, East Qatraneh, Bayir, Al-Abyad, Al-Hasa and Mshash Hodroj in the south.
5.2 Refinement of site selection

Results of initial selection were presented and discussed during the meeting with the representatives of governmental institutions working in the area of rangeland development. The meeting, held at the Ministry of Agriculture (MOA) on 18th of December 2014, was led by his
Excellency the Secretary General of MOA (Dr Radi Al-Tarawneh) and representatives from the Ministry of Environment, Badia Restoration Program (BRP), Ministry of Planning and IUCN. The discussions focused on the objectives behind the concept of investment in rangelands and the lessons learned from previous and current projects. Based on these discussions, the MOA suggested to include more criteria for selection and to include other geographic where MOA had worked and established rangeland reserves that showed good potential for rehabilitation (Figure 11). The criteria for refining the selection are summarized in Table 2.

Table 2: Summary of criteria for refined selection of rangeland sites.

<table>
<thead>
<tr>
<th>Factor /Parameter</th>
<th>Criteria for selection (inclusion)</th>
</tr>
</thead>
</table>
| Vegetation        | - Selected sites shall include different types of vegetation and wide ranges of NDVI.  
                    | - Condition of vegetation: high potential for recovery as indicated by field visits and previous work of Ministry of Agriculture.  
                    | - Areas must be important for local communities (in terms of grazing resources). |
| Ecological importance | - Areas that include different bioclimatic gradient or rangeland ecosystems. |
| Land use plans    | - Areas that show no conflict with other activities (industrial, mining, housing and tourism) in the present or in the near future. |
| Social            | - Areas with communities that showed interest or previous experience in community-based participation in rangeland protection. |

Following the meeting at the MOA, another meeting was held at IUCN to discuss and refine selection of sites. The meeting was attended by the head of Rangeland Department at MOA (Dr. Wael Al-Rashdan), the Director General of BRP (Dr. Marwan Suifan), the IUCN representatives and the IUCN rangeland expert (Prof. Mahfouz Abu Zanat). During this meeting, suggestions were made to include at least one area that extends into Jordan Rift Valley and one area in the southern Badia. A map for rangeland reserves of MOA was provided by Dr. Al-Rashdan with a list that showed areas with good recovery of vegetation.
Field visits were made by GIS expert (Prof. Al-Bakri), Rangeland expert (Prof. Abu Zanat), IUCN crew and the MOA representative (Dr. Al-Rashdan) to finalize selection. During field visits, characterization was made for vegetation condition, accessibility to site and importance of the rangeland site to the local community. Face-to-face interviews were also made during these visits. Based on the findings from these visits, four selected sites were recommended to start up the plan of investment in rangelands. The plan should be then scaled up for selected watersheds. The selected sites for initial stage were Hima Bani Hashim in Zarqa, kharraneh-
Fraisheen in the upstream of Ash-Shomari, Ayra-Yarqa Reserve on Wadi Al-Hssainiyyat and Wadi Shouaib, Husseiniyeh reserve north of Ma’an (Figure 12). The selected sites constitute about 0.6% of the country’s area, while the selected watersheds (Figure 10) for scaling up constitute about 23% of the country’s area.

Figure 12: Map of the selected sites.

5.3 Characterization of sites

Different GIS maps were used to characterize the selected sites in terms of vegetation zone, their vegetation index (NDVI) and their vegetation type according to NDVI values of the last 10
years. Also, hydrological settings and the current poverty levels of the selected sites were spatially delineated. The following subsections describe the main characteristics of the selected watersheds.

### 5.1.1 Vegetation zones
The general map of vegetation zones (Figure 13) shows that the selected sites are located within the different vegetation zones of Jordan. The site of Kharraneh-Fraisheen is located in steppe grasslands and extends into Hammada near Shaumari. The site of Bani Hashim is including the steppe zones of Batha and grasslands. The Husseiniyeh site is located in the Hammada vegetation. Among the sites, the reserve of Ayra-Yarqa is unique and includes the Mediterranean non-forest vegetation (mixed steppe) and extends into the Saharo-Arabian vegetation and Sudanian penetration in the downstream area in Jordan Valley.

### 5.1.2 Analysis of NDVI
Analysis of the NDVI images showed that the mean values of this index are low and reflecting the arid conditions of rangelands in Jordan. The map of mean NDVI (Figure 14) showed that most of Kharraneh-Fraisheen and Husseiniyeh sites were characterized by low NDVI range of 0.10 to 0.13. The NDVI was relatively higher in the sites of Hima Bani Hashim and Ayra-Yarqa Reserve, which could reflect the relatively high rainfall amounts and the good vegetation cover in both sites.

The map of the vegetation classes derived from NDVI images (Figure 15) showed that the selected sites were located in different zones that would reflect the different land cover surfaces and vegetation types. These findings were also verified during field visits. The mean NDVI value for the selected sites is less than 0.15, while it was higher (0.16-0.25) for the sites of Hima Bani Hashim and Ayra-Yarqa which are characterized by high rainfall and better vegetation cover. These trends were also reported by previous studies in Jordan (Al-Bakri and Taylor, 2003; Al-Bakri and Suleiman, 2004).

### 5.1.3 Hydrological settings
The selected sites are located within four surface water basins in Jordan (Figure 16). These were Al-Azraq, Zarqa, Jafr and Southern Jordan Valley side wadis. The site of Kharraneh-Fraisheen drains to Al-Azraq depression towards the east while the site in Zarqa watershed drains to the northwest into Zarqa River. The site of Husseiniyeh is located within Al-Jafr basin and drains to the southeast direction, while Ayra-Yarqa site drains to the west into Jordan Valley.
from two main streams; wadi Shouaib in the east and Hssainiyyat in the middle and northern parts of the site.

### 5.1.4 Socioeconomic settings

Analysis of GIS maps showed that the selected sites are located in zones with different poverty levels (Figure 17). Based on household expenditures and income, Husseiniyeh is characterized by high levels of poverty (DOS, 2010). The other watersheds are located in areas with medium poverty levels. Generally, development of the selected sites and their watersheds will significantly contribute to local communities as it will enable them to sustain their livestock and to generate sources of income. This was clearly demonstrated by the local community of Hima Bain Hashim in Zarqa watershed. The local community of this site are currently implementing a community-based protection (Hima) and management of rangeland on a 100-ha of treasury land. During the field visit to this site, the community demand was to expand the area of Hima to 200-ha. Obviously, the development of this site would provide additional income resources for local communities.

The site of Kharraneh-Fraisheen of Shaumari is currently used by the local communities of Al-Azraq and the livestock owners from Muwaqar. The watershed of this site is well-served by watering points, as observed during field visits and meetings with local communities. Also, it is characterized by a good accessibility which would reduce the cost of development or investment in rangelands. This site is important in terms of its location on the grazing route between eastern and western parts of the Badia. A good number of historical studies and surveys are available for this site and would serve as baseline for any future development plans for this site.

The site of Ayra-Yarqa Reserve is providing important grazing resources for the local communities in the upstream and downstream areas. The developed area is only 10 ha and the demand by local community is to increase this area. The records of MOA showed high recovery rate of vegetation in this site as rainfall amounts are relatively high. The variations in slope and slope aspect and in altitudes will make increase the level of success for proposed interventions in this site. A recent study (Rawashdeh, 2012) showed that this site is rich in biodiversity and hosts more than 700 plant species, living in the different bioclimatic zones in this site.
Figure 13: Distribution of the selected sites among the vegetation zones.
Figure 14: Map of the mean NDVI (250m) for the period 2004-2013.
Figure 15: Distribution of the selected sites among the vegetation classes derived from NDVI.
Figure 16: Distribution of the selected sites among the surface water basins in Jordan.
Figure 17: Poverty levels in the districts and sub-districts of Jordan (After DOS, 2010).
# 6 Summary of watersheds characterization

The general characteristics and settings of the selected watersheds are summarized in the following data sheets. The information presented in this table was collected from intersection of different GIS maps and from observations during field visits.

<table>
<thead>
<tr>
<th>Site 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name: Hima Bani Hashim</td>
</tr>
</tbody>
</table>

### Hydrological settings
- **Watershed:** Zarqa
- **Watershed Area (km²):** 550
- **Sub-watershed:** Abu Al-Zheyghan
- **Sub-watershed area (km²):** 108
- **Main wadi (s):** Wadi Al-Bjairat, Talaat Salameh
- **Drainage direction:** South-North
- **Rainfall:** 200-250 mm

### Location
- **Name:** Hima Bani Hashim-Wadi Al-Bjairat
- **Coordinates:** 36°0'54.1"E  32°8'0.2"N
- **Area of selected location:** 14 km²
- **Relative area of the location to the sub-watershed (%):** 13
- **Ownership:** Treasury lands
- **Altitude:** 500-700m
- **Slope gradient:** 12-30% on mountain ridges, 1-2% near wadis

### Topographic features:
The location is mountainous with steep slopes (20-30%) in many parts. Two main streams are encountered and drains toward Zarqa River in the north of this location.

### Soil:
- The area is located in Northern Highlands Dissected Limestone. This land region is characterized by xeric soil moisture regime that characterizes Mediterranean areas.
- Soils are mainly Calciixerollic xerochrept, Typic xerochrept and Lithic xerothent.
- **Soil color:** red to brown soils with a dry color of 5YR 5/6, according to Munsell system.
- Darker soils are found in the areas of wadis deposits.

### Vegetation zone:
Batha-Steppe with remains of deforested areas to the west.
Site 2
Name: Kharraneh-Fraisheen

Hydrological settings
Watershed: Shaumari
Watershed Area (km²): 1050
Sub-watershed: Al-Fraisheen
Sub-watershed area (km²): 279
Main wadi (s): Wadi Al-Fraisheen
Drainage direction: West-east
Rainfall: 80-100 mm

Location
Name: Wadi Al-Fraisheen
Coordinates: 36°33’16” E  31°42’22” N
Relative area of the location to the sub-watershed (%): 25
Ownership: Treasury lands
Altitude: 600-630 m in Kharraneh, 500-530m in the downstream near Shaumari
Slope gradient: 1-5 %

Topographic features:
The location is located in the East Jordan Limestone Plateau that has flat areas with desert pavements that reaches 100% in some places. Few gullies were encountered in the eastern pats. Wide wadis in the west with shrub rangelands.

Soil:
- Arid soils of cambids and calcids dominate this site. The soils are mainly silty loam with high carbonate content.
- Gravels: inside the wadi, the gravels are continuously covered by the soil deposits carried by the floodwater. Outside the wadi, the percent cover of the black-whitish gravels may reach 100% in some places.
- Soil mounds: the floods running through the wadi created a pattern of small soil mounds around the plants, terraces and pedestaled plants.
- Soil color: gray-yellow with 2.5Y 9/4 dry color, according to Munsell system. Dark slick spots indicating soil alkalinity are found in the downstream area.

Vegetation zone:
Grassland steppe and Chert Hammada.
### Site 3

**Name:** Ayra-Yarqa

#### Hydrological settings

<table>
<thead>
<tr>
<th>Description</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watershed</td>
<td>Ayra</td>
</tr>
<tr>
<td>Watershed Area (km²)</td>
<td>45</td>
</tr>
<tr>
<td>Sub-watershed</td>
<td>Wadi Al-Hssainiyat</td>
</tr>
<tr>
<td>Sub-watershed area (km²)</td>
<td>24</td>
</tr>
<tr>
<td>Main wadi (s)</td>
<td>Wadi Bayr Al-Shaikh, Wadi Al-Darat, Wadi Al-Hssainiyat</td>
</tr>
<tr>
<td>Drainage direction</td>
<td>northeast-west</td>
</tr>
<tr>
<td>Rainfall</td>
<td>150 mm in the downstream area to 400 mm in the upstream area</td>
</tr>
</tbody>
</table>

#### Location

<table>
<thead>
<tr>
<th>Description</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Wadi Bayr Al-Shaikh-Wadi Al-Hssainiyat</td>
</tr>
<tr>
<td>Coordinates</td>
<td>35°39′12.935″E  31°58′6.894″N</td>
</tr>
<tr>
<td>Area of selected location (km²)</td>
<td>10</td>
</tr>
<tr>
<td>Relative area of location (%)</td>
<td>40</td>
</tr>
<tr>
<td>Ownership</td>
<td>Treasury lands, some privately owned unit are found in the upstream areas.</td>
</tr>
<tr>
<td>Altitude</td>
<td>-100 m in the downstream, 500 m in the upstream at the station of Ayra.</td>
</tr>
<tr>
<td>Slope gradient</td>
<td>12-27 %, 4-8% at shoulders of some mountains.</td>
</tr>
</tbody>
</table>

#### Topographic features:

The location is part of Jordan Valley Escarpment, where most of soils are formed on undulating dissected plateau on sandstone/limestone colluvium with aridic moisture and hyperthermic temperature regime.

#### Soil:

- Soils are Typic and Lithic Torriorthent with arid soils of cambids and calcids in the Jordan Valley. The soils contain considerable fraction of sands in the middle parts of the location.
- Rock exposures are found in many places, gravels are found inside the wadis in Jordan Valley.
- Soil color: variations in soil color are found in many places, the upstream area has Mediterranean soils with a Hue of 5 R while downstream areas have bright soils with low organic matter and high carbonate content.

#### Vegetation zone:

Mixed steppe in the upstream and vegetation of the Sudanian penetration in the downstream.
### Site 4
**Name:** Al-Husseiniyah

#### Hydrological settings
**Watershed:** Al-Khor  
**Watershed Area (km²):** 270  
**Sub-watershed:** Al-Ruwaishdat  
**Sub-watershed area (km²):** 109  
**Main wadi (s):** Wadi Oshosh  
**Drainage direction:** West-east  
**Rainfall:** 50-100 mm

#### Location
**Name:** Al-Husseiniyah  
**Coordinates:** 35°55' E  30°30' N  
**Relative area of the location to the sub-watershed (%):** 50  
**Ownership:** Treasury lands  
**Altitude:** 940-1100 m  
**Slope gradient:** 1-2 %

#### Topographic features:
Gravel plain overlying rocks of chalk and marl formations. Flat, very gently sloping gravel covered plateau with few silt filled depressions: scarps and pediments on calcareous rocks: plateau dissected by major wadis where shrubs exist.

#### Soil:
- Arid soils of cambids and calcids dominate this site. The soils are mainly silty to silty clay loam with high carbonate content.
- Gravels: The area of the north of the watershed is covered by gravel Hammada, while flat wadis have soil deposits that support growth of natural vegetation.
- Soil color: gray-yellow with 5 Y 9/8 dry color, according to Munsell system.

#### Vegetation zone:
Chert Hammada, dominated by shrubs in the wadis floor.

### 7 Bibliography and References


