# Chapter 1

# Selection of benchmark research watersheds in Libya

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## 1.1 Introduction

Libya faces severe water shortages and has invested heavily in developing and transferring non-renewable water resources to the coastal areas. One renewable water resource, however, is still underutilized or is mostly lost with little benefits. Rainwater on the coastal areas, particularly in Al-Jabal Al-Akhdar, Al-Jabal Al-Gharbi, and the central zone, is partially used in agriculture, but, due to the lack of management, is mostly lost in evaporation or runoff. As a result agricultural production is low and the potential for improvement is lost.

Despite efforts to increase cereal production in the country, local production does not meet consumption needs. Wheat is mostly imported, while barley is largely produced locally with occasional imports for feed use. Grain yields are generally higher under research station conditions than in farmers' fields, indicating a large scope for productivity improvement if appropriate technology and policy options are adopted. Although grain yield is acceptable in certain areas, wheat productivity is frequently hindered by various factors. Crop management is generally inadequate and needs strengthening to improve cereal productivity under various cropping (production) systems.

Small ruminants are the major livestock in Libya and contribute to between 30% and 40 % of the country's meat production. Sheep and goats are raised in single or mixed flocks in arid and semi-arid pastoral areas, and also under an intensive system within cereal project areas in the southern regions. The production systems in Libya face several constraints and there is an urgent need to improve the productivity of sheep and goats under the current livestock production systems.

Rainwater harvesting has been an indigenous practice in Libya for hundreds of years. It concentrates rainwater through runoff into targets so it can be used efficiently in agricultural or other uses. Some of the ancient techniques are still working, but maintenance and operation is very costly and, in some instances, has become infeasible. Modern technologies can make rainwater harvesting more practical and lower in cost. Many of these technologies are available now and developments in science have contributed to their success. A special study is underway to review the past and existing rainwater harvesting works in Libya.

The problem is that farmers and communities do not have the knowledge or the means to implement suitable techniques in an appropriate way. In addition it is necessary that some approaches be tested under current conditions. The capacity of the communities and the national research program and extension services needs enhancement in the area of rainwater harvesting. Conditions are now suitable for mobilizing human and financial resources to improve the situation under appropriate physical and socioeconomic environments. Success achieved in implementing rainwater harvesting in similar areas encourages adoption of these approaches on a large scale in this location.

One reason for the low level of adoption of successful land and water management practices is the lack of specific and systematic knowledge on potential areas and suitable locations for these interventions. Suitable utilization of the land lies within the land use planning process, which seeks to optimize land use while sustaining its potential by avoiding the degradation of resources. These goals become more urgent within the expected scenario of climate change, where rainfall is expected to decrease and the probability of extreme events (such as severe storms) is expected to increase.

The suitability of a location for rainwater harvesting and management practices that improve productivity depends on the local society, farming practices, and whether the area meets the basic technical requirements of the management practices in question. When planning such systems, appropriate data must be available on the climate, soil, crops, topography, and socioeconomics of the project area. These data can be collected through a combination of field visits, site inspections, topographic and thematic maps, aerial photos, satellite images, and GIS.

This report describes the use of improved methodologies developed to identify suitable watersheds based on an integrated resources management concept. The approach integrates multi-disciplinary knowledge, GIS utilities, and verification in the field to develop and test a methodology to identify watersheds with specific characteristics – in this case, the watersheds most suited to the project activities.

The objective of this process is to select suitable watersheds in which to undertake research on three project components: (i) integrating rainwater harvesting in the agricultural systems for improved productivity in Libya; (ii) integrated improvement of wheat- and barley-based cropping systems in rainfed and irrigated areas of Libya; and (iii) improvement of small ruminant productivity in Libya; in addition to cross-cutting socioeconomic components.

## 1.2 Developing selection criteria

### 1.2.1 Stakeholders consultations

The benchmark watershed selection process started from the first implementation workshop of the 'Integrating rainwater harvesting in agricultural systems' held in Tripoli, Libya, February 10-17, 2009. Previous experience with a similar process of benchmark watershed selection for the *Badia* of Jordan was presented and discussed with an inter-disciplinary team of researchers. The suitability of the process to the conditions in Libya, and particularly to this project, was discussed. The participants concluded that the process is necessary before the project can proceed with activities. This is primarily because the project integrates three major components (rainwater harvesting, cereals and livestock, and cross-cutting socioeconomic components) and it would be necessary to choose watersheds that serve integrated research activities for all components. It was agreed that if one watershed is not enough to achieve all objectives, more watersheds in each area will be considered. Many participants indicated the availability of detailed data for the target area. However, upon discussion it was revealed that the data does not always cover the whole study area, but was designed to cover small areas within the whole study area, which is not suitable for the selection process. Other data that cover most of the target area are available, but are scattered. Some areas with annual rainfall below 200 mm are not covered by any of these data. This is an important consideration for the selection process, which might require the use of less detailed information.

Four groups were formed to discuss the criteria for the selection of benchmark watersheds. These groups were rainwater harvesting, crops (cereals), small ruminants, and socioeconomics. Each group reported the main criteria, which were discussed by the group as a whole. For each group, a set of criteria was determined as being the most important for site selection (Appendix A). All criteria were processed and amalgamated to produce one set of criteria which took into consideration all factors. This set of criteria was distributed to all interested participants (the inter-disciplinary team of experts) from the Agricultural Research Center, Libya (ARC) and ICARDA. This team commented on the criteria and all team members were satisfied with the criteria and their ratings.

Some criteria required detailed informa tion (for example pH, electrical conductivity (EC), and others) that might not be available from the small scale maps and available data. In this case the criteria were simplified and were considered during the field visits. The participants indicated that the incorporation of a minimum number of criteria would be better than including many. The complete process would be verified during the field visits, when any missing criteria or important aspects would be taken care of.

The process was enriched by the inter-disciplinary team of national and international scientists visiting the field. The purpose was to get a clearer view of the environmental and socioeconomic conditions of the area, which benefited the whole selection process.

### 1.2.2. Al-Jabal Al-Gharbi field assessment

The field assessment included a transect from the coastal area, south through the mountains, to the desert areas. Several cropping (production) systems were observed, including rangelands, crops, fruit trees, and mixed systems. Following are some remarks from the field visits:

- Many areas were identified as part of a possible benchmark research watershed. These areas, which included cereal production, livestock, olive trees, and rangeland, were suitable for rainwater harvesting. Barley is the most common cereal, while wheat is mainly grown in the irrigated projects in the south
- Barley and wheat trials from ICARDA were planted at the Sofit research station, along with the national program of breeding and agronomy trials. The station has been used for cereal breeding since the early 1990s
- An option of selecting a watershed that drains to the south might be considered as there is gradual change in slope and soil toward the south. Watersheds draining to the north (towards the sea) include the Gefara plain where irrigation is dominant. Generally as we moved south, rainfall amounts were lower and land degradation becomes very obvious (poor vegetation cover, overgrazing, and soil erosion)
- The area close to Sofit station is cultivated with fruit trees. Tabias (contour earth dikes) have been implemented in some of the orchards on sloping lands. There is great potential for implementing rainwater harvesting techniques for trees to improve productivity in this area. This might generate obvious results that would be appreciated by the inhabitants
- The land tenure regime might add some complications. In this area, land is owned by the government and is given to a certain tribe to be subdivided between the members of the tribe. Land ownership is not secure, but as far as these people are concerned there is no danger of them losing use of their land. Another important aspect in the area with low rainfall (< 200 mm) is that there are no actual farmers; there are many pastoralists who are not involved in cultivating or improving the rangeland, but simply use it. This is an important consideration for rainwater harvesting development projects.

### 1.2.3. Al-Jabal Al-Akhdar field assessment

- Most of the southern part of Al-Jabal Al-Akhdar is located within a low rainfall area. Barley is planted in the bottom of *wadis*, depressions, and in water collection areas, showing the great demand for feed. The area of Al Marj might be more suitable for the project purposes
- Al Marj research station is located in a typical barley and wheat growing area. Cereal yields in farmers' fields are low, around 1 t/ha. The main reason being the low adoption of fertilizer application. In contrast, the barley and wheat breeding trials in the station are all grown under optimum fertilizer application. The strategy is to identify lines that perform better under fertilizer application, and not in farmers' fields
- Most of southern part of Al-Jabal Al-Akhdar is located within a low rainfall area with little chance of growing cereal crops. It was generally concluded that watersheds that drain towards Al Marj area might be more suitable for the project purposes.

A work plan to organize the watershed selection process was prepared. Given the time limitations associated with starting other activities based on this process, it was agreed that some simplification of the process was needed (by making only one field visit to five watersheds in each of the two sites). And, assuming that data would be made available in a short period of time, a special inter-disciplinary team decided the selection of watershed(s) in the two study areas.

### 1.2.4. Development of watershed selection criteria and verification

A first set of criteria was developed by consulting the results from the thematic group discussions of the interdisciplinary team during the first workshop in Libya and by referring to relevant documents (Oweis et al., 2001; Ziadat et al., 2006). These criteria compromise the various requirements of the four groups (rainwater harvesting, cereals, livestock, and socioeconomic).

Therefore, all these requirements are taken into consideration, not just the requirements of one group. In addition to these criteria, the following aspects were examined during the inter-disciplinary field visits:

1. Major hydrological characteristics of the area
2. Safety for research implementation (equipment)
3. Population density
4. Willingness of the community to cooperate
5. Land tenure system (use rights and property rights)
6. Proximity to research station(s)

Any criteria for which data was not available would be looked at during the field visits using the experience of the interdisciplinary team. The figures presented for this set of criteria represent the best values, but that does not mean that the occurrence of less favorable classes would be a reason to exclude the watershed. Therefore, during the application of these criteria in the GIS, high scores were given to watersheds that included a high percentage of the criteria, but that did not mean that other values are not included within the watershed. For example, a high score is given to a watershed with a large proportion of its area receiving an annual rainfall of between 100 mm and 300 mm (preferred for rainwater harvesting and livestock), but it was still important to include areas with an annual rainfall of between 300 mm and 500 mm (more preferred for cereals). It was anticipated that this approach would satisfy all groups and help to select watersheds that suited all requirements. Field visits were also another means to ensure that the various groups were satisfied with the selected watershed(s). This will be explained later in more detail.

This set of criteria was sent to all the scientists involved. Feedback was received and the comments from various team members were compiled and considered. The comments and suggestions were specific to each group as well as being more general with greater emphasis on the integrated nature of this project. The four groups would be working together within a watershed and therefore it was necessary that the selected watershed satisfied all needs and demands, both individually and collectively. Based on all the comments and suggestions, a revised version of the criteria was sent out for final comment by all team members. The comments from the first round indicated some contradictions between the needs of the different groups and, therefore, a compromise was made to satisfy all groups.

This second round of collecting comments and suggestions was very important. The team indicated their satisfaction with the new version and this was considered for further processing. (Table 1.1) shows these criteria and their scores. The best conditions were given a score of 10 and the worst were given a score of zero.

## 1.3 Data collection and processing

Based on the criteria for watershed selection that has been explained in the previous section, the required data were determined. These data were collected from various sources and are explained under two categories, data from the GIS unit at ICARDA (GISU) (global data) and data collected from Libya. The data from the GISU include the outline of the study area, climate mapping, remote sensing, digital elevation model, and other secondary data sources. The data from Libya include soil data, cropping (production) systems, community (settlements), small ruminant density, and road and track networks.

### 1.3.1. Outline of the study area

The 'agricultural regions' were prepared by the GISU and the methodology is explained in a separate report (De Pauw, 2009). The 'agricultural regions' were defined as integrated spatial units, in which particular water resources and climate, terrain, and soil conditions combine to create unique environments that are associated with distinct land use patterns, farming systems, and settlement patterns.

The concept of 'agricultural regions' has been developed to address the need for a single synthesis map that shows the unity between natural environments, production systems, and livelihood systems. As experience from other countries indicates, such a synthesis map characteristically contains a limited number of spatial units (e.g. 27 in the case of Syria, and 31 for a comparable map of 'régions agricoles' in Morocco). Typically, this kind of mapping accentuates individuality rather than communality. Each mapping unit has its own 'personality' that is different from any other mapping unit, and therefore requires an individual description. The characteristics of the units are not predictable ex-ante, because in one unit the key characteristic could be high aridity, in another it could be the presence of mountains, while in yet another it could be a unique agricultural system.

The concept of 'agricultural regions' as applied to Libya combines dominant biophysical criteria and major agricultural systems. In this study the identification of such 'agricultural regions' was based on remote sensing, with validation through expert knowledge and ground-truthing, supported by auxiliary analyses and data sources.

*Table 1.1. Watershed selection criteria approved by the inter-disciplinary team of researchers*

| Criteria | Units | Score | | | Remarks |
|---|---|---|---|---|---|
| | | 0 | 5 | 10 | |
| Rainfall (RWH) | mm | < 100 or > 500 | 300-500 | 100-300 | Watershed extends over wide range of rainfall |
| Cropping (production) systems | | Sizable area of only one system is available | Sizable areas of only two systems are available | Sizable areas of three systems are available | Diversity of cropping (production) systems is needed: rangeland, rainfed, and irrigated |
| Community (rural settlement) | | No sizable community inside or near watersheds | Communities available, but outside the watershed | Communities available inside and around watershed | Involvement of communities in agriculture.<br>Subject to data availability |
| Accessibility and visibility | Road network | No roads | Roads cover part of the watershed | Roads and tracks cover most parts of the watershed | |
| Topography (slope) | % | > 20 | 11-20 | 0-10 | Average within watershed.<br>Part of watershed is flat for cereals |
| Potential for rainwater harvesting | | Low | Medium | High | Stream density (total length of streams/ total area of watershed) |
| Soil type | Class | Watershed includes one or two dominant soil types | Watershed includes a few dominant soil types | Watershed includes many dominant soil types | Watershed to cover most soil types that are dominant in the ecosystem |

*Table 1.1. Continued*

| Criteria | Units | Score | | | Remarks |
|---|---|---|---|---|---|
| | | 0 | 5 | 10 | |
| Soil depth | cm | More than 50% of the watershed has < 30 | More than 50% of the watershed has 30-100 | More than 50% has > 100 | Average for dominant soil type(s) |
| Soil limitations | | Soils with salinity, $CaCO_3$, shallowness, rockiness are dominant | Soils with either salinity, $CaCO_3$, shallowness, or rockiness are dominant | Soils with salinity, $CaCO_3$, shallowness, rockiness are not dominant | Subject to data availability |
| Soil salinity | dS/m | More than 50% of the watershed has > 10 | More than 50% of the watershed has 4-10 | More than 50% of the watershed has < 4 | Subject to data availability |
| pH | | <7 OR >8.5 | 8-8.5 | 7-8 | Subject to data availability |
| Small ruminant density | Number | Low | Medium | High | |
| Water points (WP) | | No water points in the watershed | Few water points (distance between WP > 20km) | Sufficient water points (distance between WP < 15 km) | |
| Availability of research stations, weather stations, data, runoff records, institutes, etc | | | | | Criteria to differentiate between potential watersheds |

Based on the discussion during the first workshop, it was agreed that the study area would focus on two ‘agricultural regions’ (Cyrenaica in the east and Tripolitania in the west) (Figure 1.1). The outline of the study areas in the east and in the west were derived from the agro-ecological zone (AEZ) map. All the data were made available to cover these two study areas.

Hutchinson (1995), as implemented in the ANUSPLIN software (Hutchinson, 2000), was used to convert the station-based climatic database into ‘climate surfaces’.

The Hutchinson method is a smoothing interpolation technique in which the degree of smoothness of the fitted function is determined automatically from the data

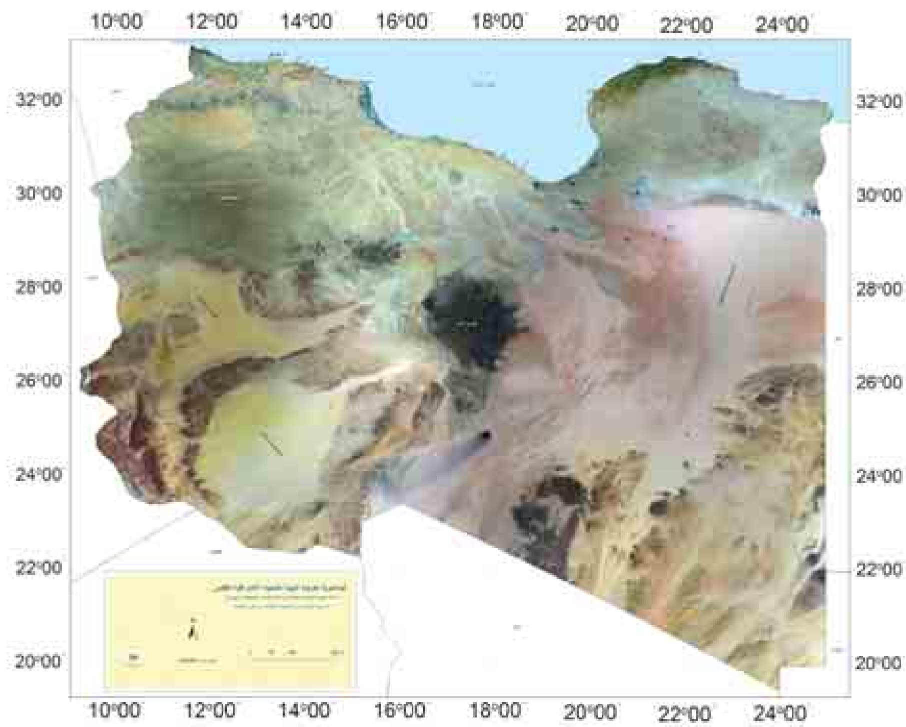


*Figure1.1 Outlines of the two study areas in the east and west of Libya*

**1.3.2. Climate mapping**

Precipitation and temperature data from climate stations inside and outside Libya were converted into gridded maps of mean monthly and annual precipitation and minimum and maximum temperature with 30 arc-second spatial resolutions (approximately a 1 km grid cell). All data were obtained from the FAOCLIM2 database (FAO, 2001). For the spatial interpolation of precipitation, 101 stations were available – 94 inside Libya, one in Algeria, three in Tunisia, two in Egypt, and two in Chad. The ‘thin-plate smoothing spline’ method of

by minimizing a measure of the predictive error of the fitted surface, as given by the generalized cross-validation (Hutchinson, 2000). The method uses three independent spline variables – latitude, longitude, and altitude. The latter was input into the model in the form of a digital elevation model (DEM) ASCII grid file. The DEM used to generate the climate surfaces was the SRTM30 DEM with 30 arc-second resolution. Parameter estimation was undertaken over a regular grid with the same dimensions and resolution as the user-provided DEM.

The gridded surfaces of mean monthly minimum and maximum temperatures and potential evapotranspiration were obtained by clipping using a Libya vector boundary mask from the corresponding regional surfaces for Eurasia and North Africa, developed earlier by the ICARDA GIS Unit (De Pauw, 2008). The boundary mask for Libya was derived by updating the country boundary shape file from the digital chart of the world with the vector coastline mask derived from SRTM30 –the SRTM Water Body Data (SWBD).

The annual precipitation surface was used to develop, in ArcGIS, a grid mask of the areas in Libya with annual precipitation higher than 100 mm (Figures 1.2a and 1.2b). Outside these areas precipitation is too low for agriculture, either for crops or livestock, to be feasible.

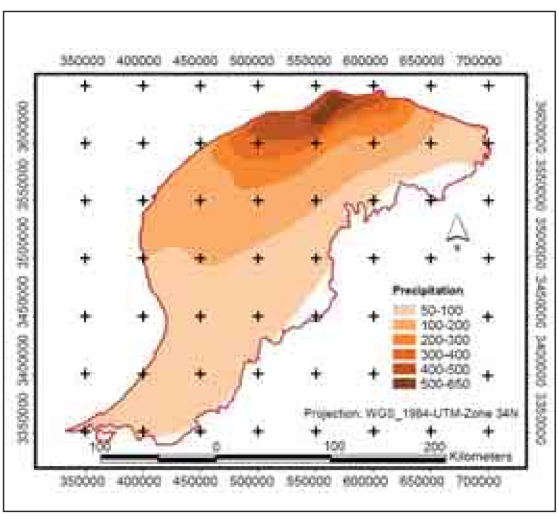


*Figure 1.2a. Rainfall distribution over the eastern study area*

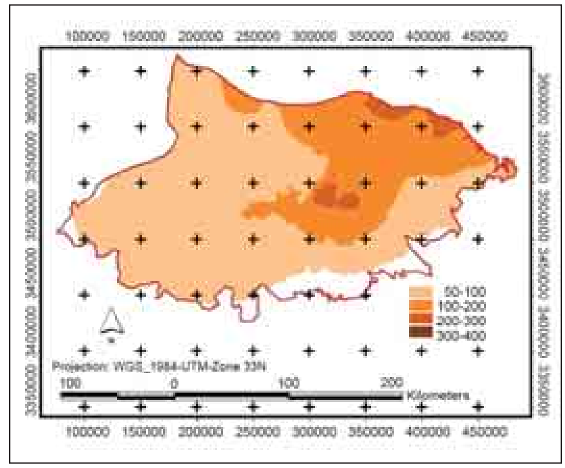


*Figure 1.2b. Rainfall distribution over the western study area*

### 1.3.3. Using remote sensing data

The 100 mm precipitation mask was the basis for the visual interpretation of recent satellite imagery, supported by the above mentioned secondary information, to delineate the boundaries between the regions.

The imagery used was extracted for Libya from the 2000 Geocover series of ortho-rectified Landsat 7 ETM+ mosaics. This dataset is from the Landsat 7 Enhanced Thematic Mapper (ETM+) with the 15 m panchromatic band fused with the 30 m multi-spectral bands 7-4-2. The projection is Universal Transverse Mercator (UTM)/ World Geodetic System 1984 (WGS84). Apart from ortho-rectification, these Landsat images have been tonally balanced, mosaiced, tiled, and wavelet compressed. They are of the highest quality. The spatial extent of each mosaic used is shown in (Figure 1.3). The coverage date is scene-dependent, nominally 2000 +/- 2 years. The images were clipped to include only the two study areas in the east and west (Figures 1.4a and 1.4b).

The 'professional' version of Google Earth (Google Earth Pro) was used to 'zoom' in on each of the 'agricultural regions' and view a high-resolution QuickBird image as a form of ground truthing. QuickBird is currently the highest resolution commercial optical satellite (operated by Digital Globe) and provides, through Google Earth, multi-spectral imagery at a resolution of 2.44 m, making small or narrow

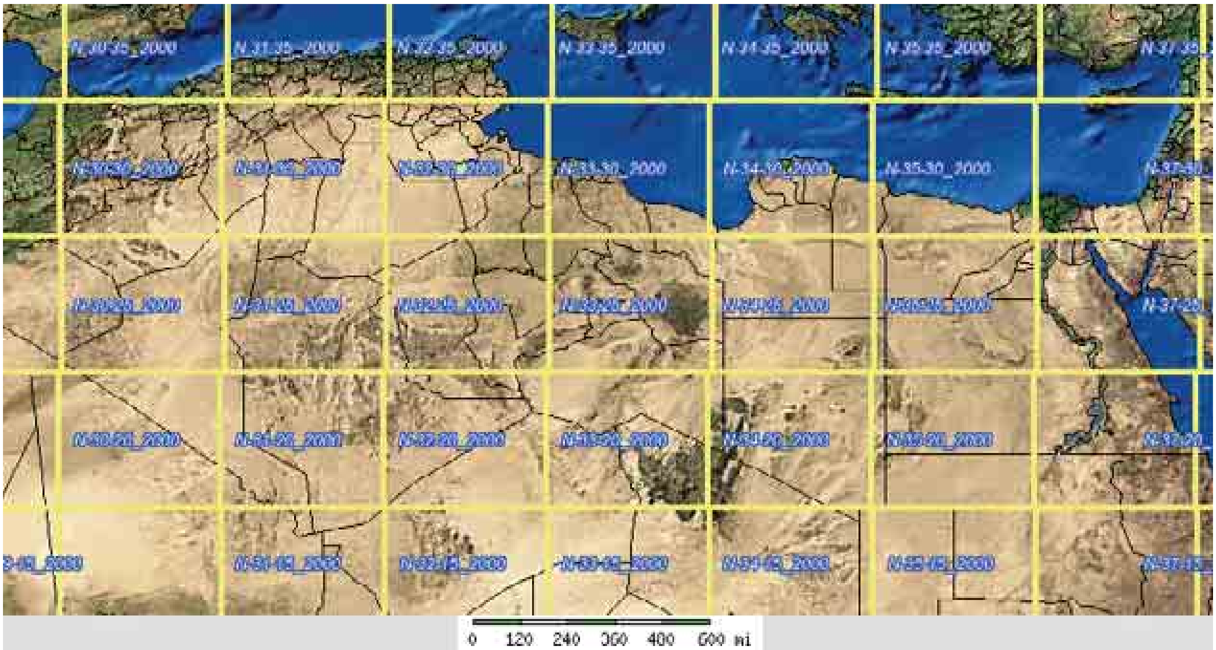


*Figure 1.3. Geocover imagery covering Libya and neighboring countries*

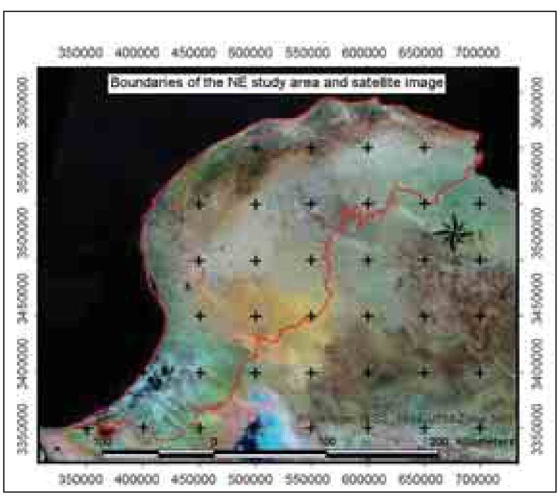


*Figure 1.4a. Satellite image covering the eastern study area*

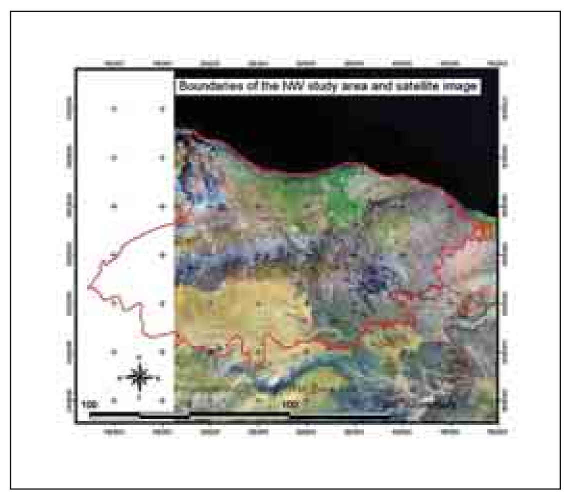


*Figure 1.4b. Satellite image covering the western study area*

objects, such as trees, tracks, check dams, plowing, drainage lines, and houses, visible. QuickBird imagery is available for between 60% and 70% of the 'agricultural regions' of Tripolitania and Cyrenaica. More direct ground truthing was provided by visual observations of land use/land cover (LULC) carried out during two field visits to Tripolitania and Cyrenaica (June 2008 and February 2009). These 481 point observations were recorded with a handheld global positioning system (GPS), and overlaid onto the Google Earth and Geocover imagery.

### 1.3.4. Digital elevation model and other secondary data sources

In addition to the information extracted from the Geocover Landsat, and Google Earth QuickBird archives, characterization of the 'agricultural regions' was based on secondary data. The main data sources were the shuttle radar topographic mission (SRTM) DEM, the geological map of Libya, the soil map of Libya, and literature collected from the Internet.

The SRTM DEM was the source of major topography-related data, such as elevations, slopes, watersheds, and drainage lines. Slope was calculated using the slope function of the spatial analyst tools in Environmental Systems Research Institute, Inc. (ESRI) ArcGIS software (Figures 1.5a and 1.5b).

Watersheds and drainage lines were delineated using the Arc Hydro Tools utility for ArcGIS. Using the SRTM DEM as the input grid, the following steps were followed to create watersheds and drainage lines:

- Fill sinks: if a cell in the DEM is surrounded by higher elevation cells, the water is trapped in that cell and cannot flow. The Fill sinks function modifies the elevation value to eliminate these problems
- Flow direction: create a flow direction grid from a DEM grid
- Flow accumulation: create a flow accumulation grid from a flow direction grid
- Stream definition: create a new grid (stream grid) with cells from a flow accumulation grid that exceeds a user-defined threshold
- Stream segmentation: create a stream link grid from the stream grid (every link between two stream junctions gets a unique identifier)
- Catchment grid delineation: create a catchment grid for a link grid. It identifies areas draining into each link
- Catchment polygon processing: create catchment polygons out of the catchment grid
- Drainage line processing: create streamlines out of the stream link grid.

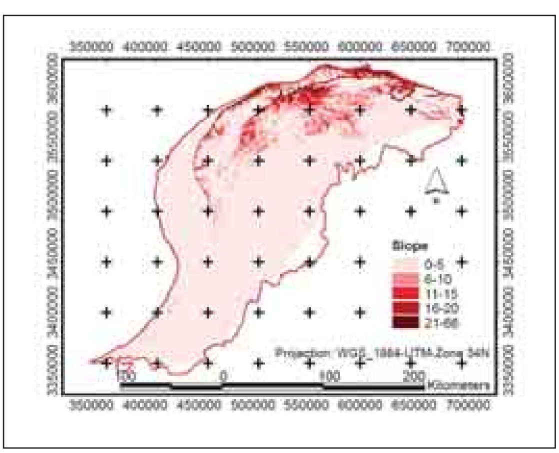


*Figure 1.5a. Slope classes for the eastern area*

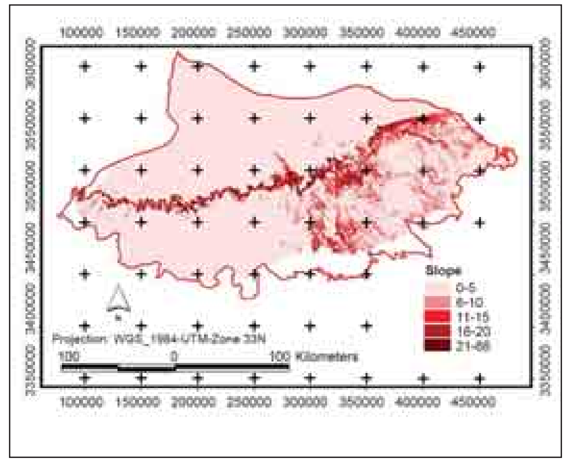


*Figure 1.5b. Slope classes for the western area*

Watersheds and drainage lines were created at three different levels, with 100,000, 50,000, and 25,000 upstream pixels as thresholds. With a 25,000 pixel threshold there are more watersheds, which are nested into a smaller number of 50,000 pixel threshold watersheds, and these in turn are nested inside fewer 100,000 pixel threshold watersheds. Watersheds and drainage lines that were created with 50,000 upstream pixels as thresholds were used in subsequent analyses (Figures 1.6a and 1.6b).

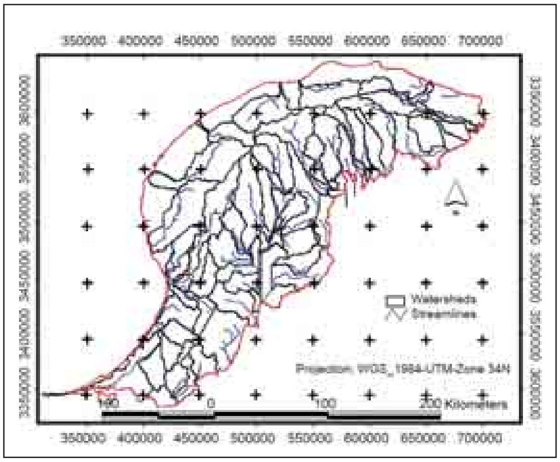


*Figure1.6a. Watersheds and drainage lines for the eastern area*

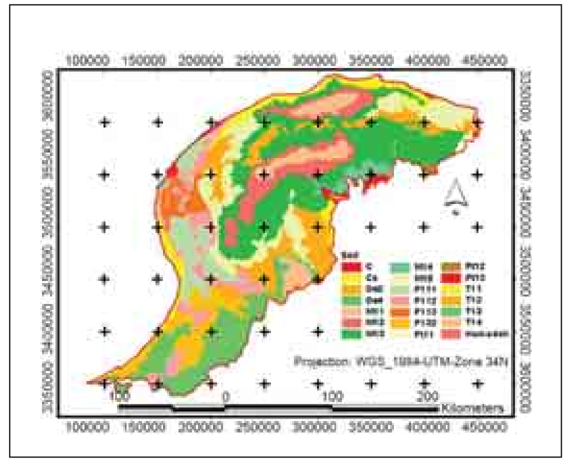


*Figure 1.7a. Soil map (scale 1:2,000,000) of the eastern area*

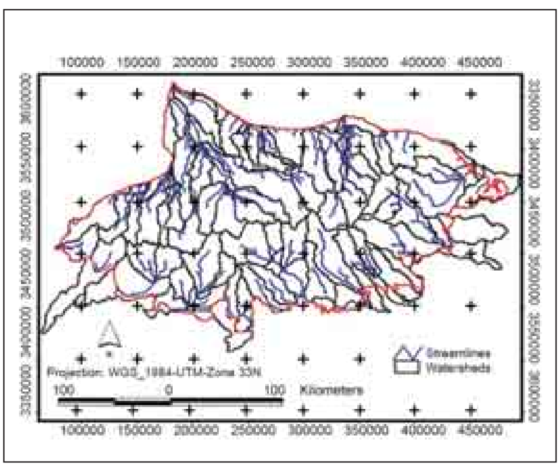


*Figure 1.6b. Watersheds and drainage lines for the western area*

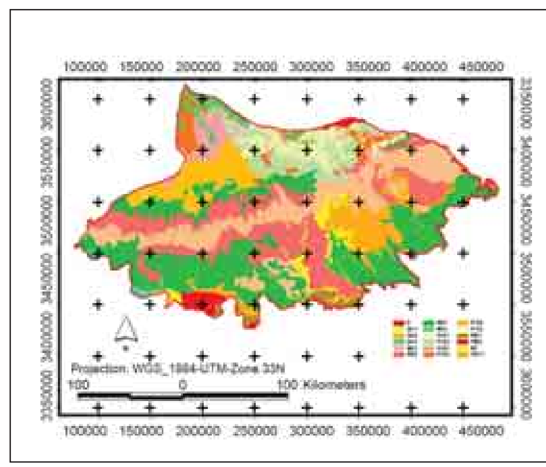


*Figure 1.7b. Soil map (scale 1:2,000,000) of the western area*

**1.3.5. Soil data**

The best available soil map was at a scale of 1:50,000. However, this map does not cover the whole study area in west and east Libya. The original survey was meant to cover areas with annual rainfall higher than 200 mm. The interest of this project extends beyond this area to cover areas with an annual rainfall higher than 100 mm. The best available soil data that covers the whole study area was at a scale of 1:2,000,000 (Figures 1.7a and 1.7b).

This map includes associations of soils within the soil mapping units; the percent of each association is recorded. The map satisfied the needs of the project at this preliminary stage. The particular data needed about soil are available from the description of the soil association and using the keys to soil taxonomy. The main limitations of soil association were carbonate, soil depth, soil salinity, and the presence of sea shore sand.

### 1.3.6. Cropping systems

The available land use map was used to derive information on production systems and LULC. The scale of this map was 1:50,000 and was derived using the legend of the FAO land cover classification system (LCCS). This map was prepared previously during the mapping project of Libya. The following steps were followed in the preparation of the map; field work, interpretation of satellite images (scale 1:50,000), collection of ground truthing observations using GPS (accuracy from 5 m to 10 m), followed by office interpretation, and field checking. The original legend of these maps includes the following classes:
*For the eastern area* (Figure 1.8a):

- **IL** irrigated land
- **RL** rainfed land
- **NV** rangeland
- **BC** bare soil consolidated
- **BU** bare soil unconsolidated
- **NF** natural forest
- **UB** urban

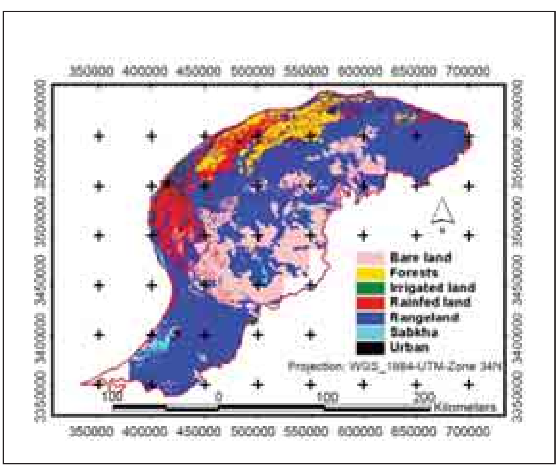


*Figure 1.8a. Land use/land cover classes for the eastern area*

For the western area (Figure 1.8b):

- **IL** irrigated land
- **RL** rainfed land
- **NVF** natural forest
- **BL** bare land
- **F** reforestation
- **SB** sabkha
- **UB** urban

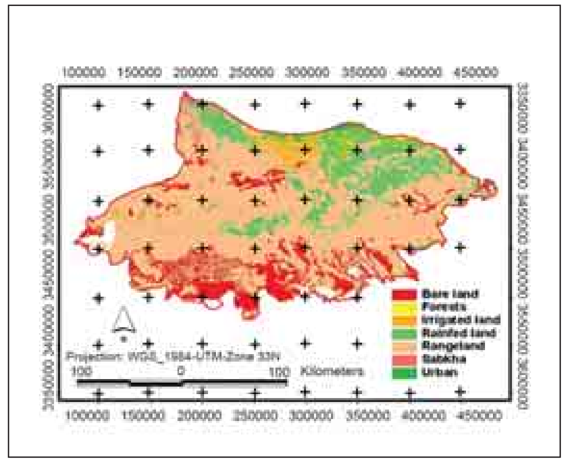


*Figure 1.8 b. Land use/land cover classes for the western area*

### 1.3.7. Road network and community (selection)

The spatial distribution of settlements (geographic location) over the watershed subdivision was mapped from various sources. The preliminary sources were topographic maps at a scale of 1:50,000. Field checks revealed that some communities do not exist on the maps. Therefore other sources of information were consulted to get a better coverage of this important information. Among these were the satellite images explained before and Google Earth. The data from these sources were compiled into one data layer (Figures 1.8a and 1.8b). The road network was derived from 1:50,000 topographic maps (Figures 1.9a and 1.9b).

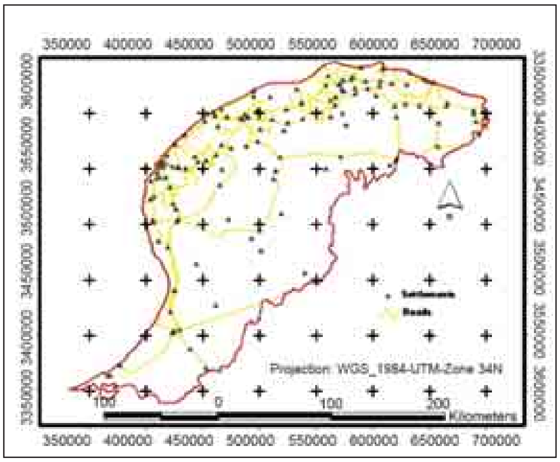


*Figure 1.9a. Distribution of roads, towns, and villages for the eastern area*

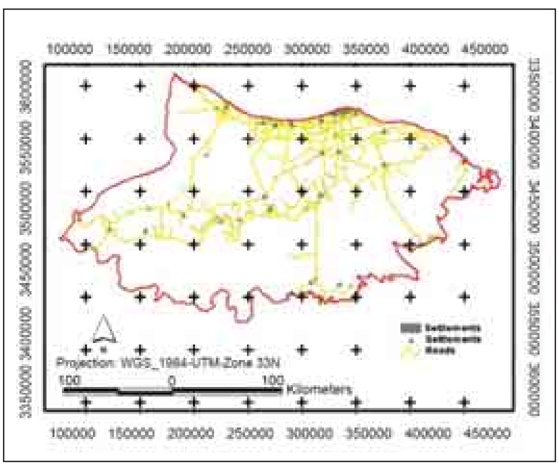


*Figure 1.9b. Distribution of roads, towns, and villages for the western area*

## 1.4. Approach for analyses

The watershed selection criteria agreed by the inter-disciplinary team were applied to the collected data and some watersheds were selected. At this stage only four criteria were used – rainfall, cropping (production) system, community, and accessibility and visibility. This was used to test the methodology, get feedback from team members, and then develop a robust approach for watershed selection. Two approaches to undertake the selection process were possible. The first was to apply the scoring reported in (Table 1.1) for each watershed and then use the summation of scores for all criteria to classify the watersheds from best to worst with respect to their satisfying the project objectives. The main advantage of this approach is its simplicity and reproducibility. However, a disadvantage is that some watersheds might be excluded because one of the criteria is not satisfied, even when all other criteria were ideal. Furthermore, the approach is not flexible enough to accommodate the diverse requirements assigned by the four project components and simply find watersheds that satisfy all. For example, the rainwater harvesting team was looking for that part of the watershed with an annual rainfall of between 100 mm and 300 mm and a slope in the range 0% to 10 %, while the crop improvement team was looking for that part of the watershed with a higher rainfall and probably less steep slopes. Simple scoring of the whole watershed would certainly use the average of these criteria to assign one score for the whole watershed, which would not accommodate the needs of the various components.

The preliminary results of applying this approach were presented and discussed with representatives from various components. The masks of cropping (production) systems (Figures 1.8a and 1.8b), rainfall (Figures 1.2a and 1.2b), watershed boundaries (Figures 6a and 6b), and distributions of communities and roads (Figures 1.9a and 1.9b) were overlaid and interactively and visually analyzed. The capabilities of the GIS to overlay different masks, zoom in and out, and make queries were implemented to enrich the live discussion about the whole process of watershed selection. The advantages and disadvantages of the selection process were discussed and suggested modifications were formulated.

Based on this meeting, an alternative approach was followed after discussion with all team members. This alternative approach was to look at the variability of various criteria within each watershed and try to characterize the watershed based on this variability and how good or bad the watershed is in terms of satisfying the various needs of all components. This is simply an elimination process of those watersheds that are obviously not close to satisfying the project objectives. The process started with the application of one criterion (rainfall for example). Each watershed where the evidence indicated that it was not suitable for the project (for example a large proportion of the watershed lies in an area with a rainfall of less than 100 mm) was then eliminated. The process is then repeated for the next criterion and so on for the rest of criteria. Finally, the watersheds which are selected after screening for all criteria are those with potential for the project. The implementation of this approach for each criterion is explained in the following sections and then the final selection of the potential watershed is explained.

### 1.4.1. Rainfall

The watershed map (Figures 1.6a and 1.6b) was overlaid with the rainfall isohyets map (Figures 1.2a and 1.2b). Each watershed was characterized in terms of the minimum, maximum, and average rainfall (Figures 1.10a and 1.10b).

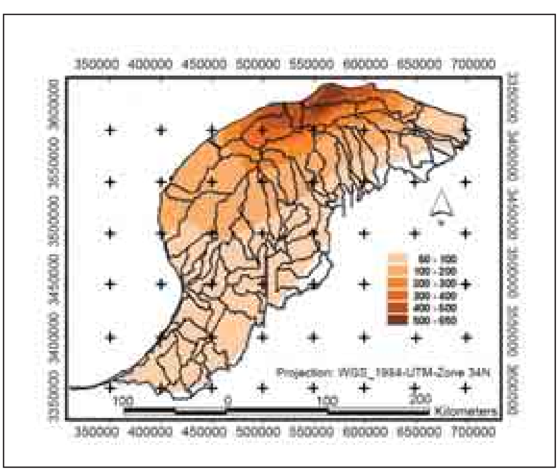


*Figure 1.10a. Watershed boundaries and rainfall distribution for the eastern area*

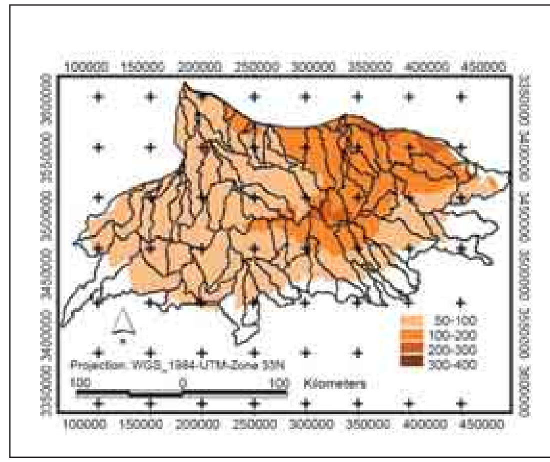


*Figure 1.10b. Watershed boundaries and rainfall distribution for the western area*

Watersheds which fall completely outside the range of rainfall that is suitable for this project were eliminated – for instance, watersheds with majority of their areas located in zones with less than 100 mm or more than 500 mm annual rainfall.

These were not considered for any further analyses. The rest of the watersheds were analyzed to apply the remaining criteria. During the meeting to discuss the preliminary selection of the watershed, the selection criteria were fine-tuned. It was agreed that, based on the preliminary selection, the selection of only one watershed in the east and only one watershed in the west satisfying all components might not be possible given the diversity of requirements to satisfy all components. Therefore, the analyses must consider that the project might select two or more watersheds where different components are satisfied. It was suggested that one watershed might be used for rangeland and rainwater harvesting with rainfall between 100 mm and 300 mm and another watershed for rainfed cropping and rainwater harvesting with rainfall between 300 mm and 500 mm. Based on this, the criteria limits in Table 1.1 were detailed in a more practical way (Table 1.2). This detailed criteria defined a lower limit and an upper limit for rainfall. These limits were derived from the actual requirements of each activity and were detailed for the eastern and western areas separately.

Applying the first scenario in (Table 1.2) (select only one watershed) resulted in just five watersheds in the eastern area and six watersheds in the western area that were suitable for this project from a rainfall point of view (Figures 1.11a and 1.11b).

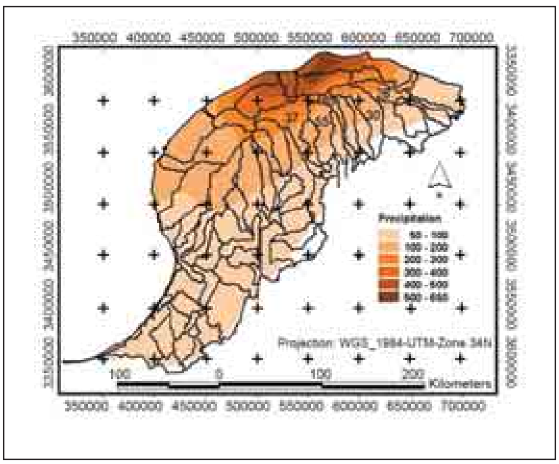


*Figure 1.11a. Watersheds that have a rainfall range between 100 mm and 500 mm (suitable for all project components) in the eastern area*

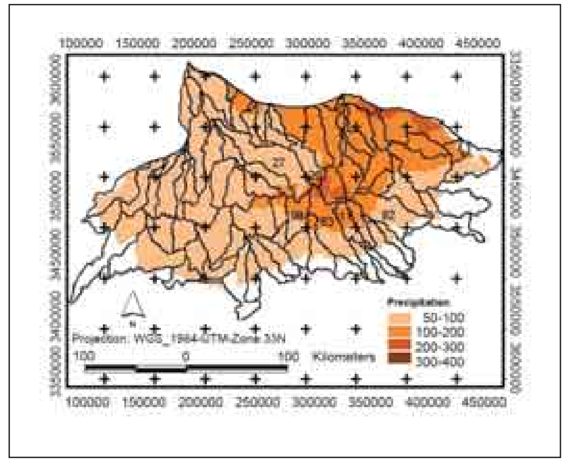


*Figure 1.11b. Watersheds that have a rainfall range between 100 mm and 500 mm (suitable for all project components) in the western area*

However, applying the second scenario in (Table 1.2) (allow the selection of two watersheds) resulted in 26 watersheds in the eastern area and 28 watersheds in the western area that were suitable for this project from a rainfall perspective (Figures 1.12a and 1.12b). These might be considered for rainfed cropping only, rangeland only, or for both uses in the same watershed (see the legend). These watersheds were considered for further analyses to include the rest of criteria and achieve the final selection of the watersheds.

***Table 1.2. Detailed criteria limits for rainfall***

| | One watershed | | Two watersheds | | | |
|---|---|---|---|---|---|---|
| | | | Rangeland | | Rainfed | |
| **Area** | **Lower limit (mm)** | **Upper limit (mm)** | **Lower limit (mm)** | **Upper limit (mm)** | **Lower limit (mm)** | **Upper limit (m)** |
| Original criteria | 100 | 500 | 100 | 300 | 250 | 500 |
| East | ≤150[1] | ≥350[2] | ≤150[1] | ≥250[3] | ≤250[4] | ≥350[2] |
| West | ≤150[1] | ≥300[2] | ≤150[1] | ≥250[3] | ≤250[4] | ≥300[2] |
| Actual criteria[5] | | | | | | |
| East | 97-146 | 363-503 | 98-163 | 245-319 | 200-499 | 349-652 |
| West | 98-152 | 293-402 | 93-197 | 229-281 | 182-268 | 300-404 |

[1] rainwater harvesting for rangeland not more than 150 mm
[2] necessary for wheat, not less than 350 mm in the eastern area and not less than 300 mm in the western area
[3] necessary to implement various types of rainwater harvesting interventions
[4] lower limit for rainfed barley
[5] actual limits that were applied based on the actual data available for the east and west

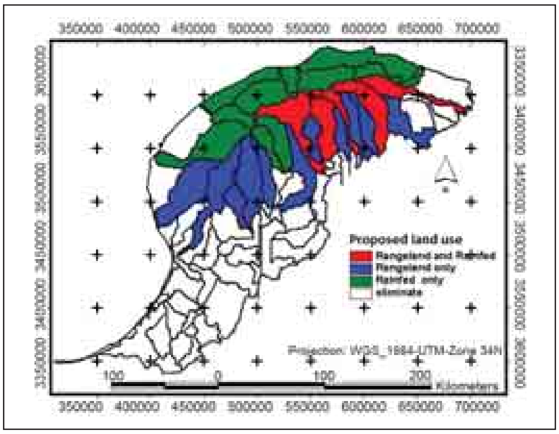


*Figure 1.12a Watersheds that have a rainfall range between 100 mm and 300 mm (rangeland only), or between 300 mm and 500 mm (rainfed only), or between 100 mm and 500 mm (rangeland and rainfed) in the eastern area*

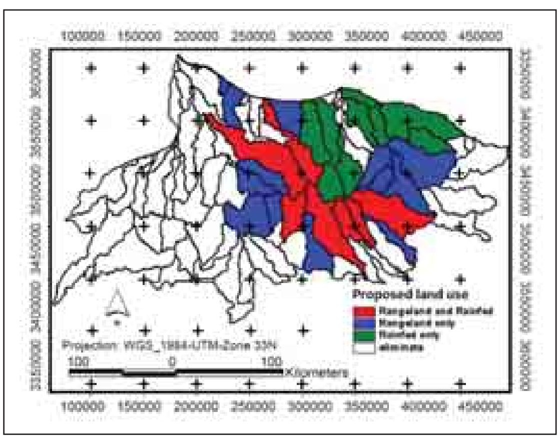


*Figure 1.12b Watersheds that have a rainfall range between 100 mm and 300 mm (rangeland only), or between 300 mm and 500 mm (rainfed only), or between 100 mm and 500 mm (rangeland and rainfed) in the western area*

### 1.4.2. Cropping systems

The area of different LULC was estimated to ensure that not only the rainfall criteria match the required cropping (production) system, but also that there is a sizable area of the intended uses within the watershed.

Considering the presence of irrigated areas within the watershed helps the selection criteria narrow down the options considerably. Therefore, we could select watersheds without irrigated areas within their boundaries. This would give more flexibility in the selection. Beside, suitable areas for irrigation might be there, but the land is not currently under irrigation, so we can relax this criteria.

Maps of the distribution of the cropping (production) systems (Figures 1.8a and 1.8b) were overlaid with the maps of the watershed boundaries (Figures 1.6a and 1.6b) and the area of each cropping (production) system within each watershed was calculated. The important classes of the LULC map for this project are rainfed and rangeland (Figures 1.8a and 1.8b). Therefore, these two classes were considered in this analysis. Based on the presence of significant areas of different cropping (production) systems within the watersheds, the intended use of some watersheds was changed. In the eastern area, four watersheds were changed from being considered for rainfed and rangeland (based on rainfall criteria) to be considered for rangeland only because the analysis indicated that the area under rainfed agriculture was not enough to support the implementation of rainfed research (Figure 1.13a). In these watersheds the *wadi* floor and flat area around the *wadi* in a very low rainfall area were

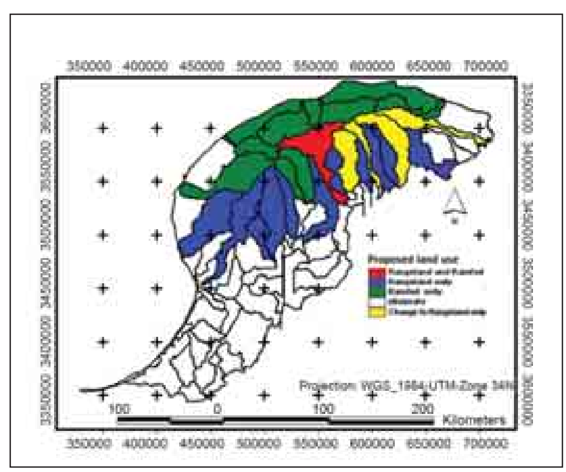


*Figure 1.13a Changing a watershed's intended use based on the availability of sufficient land use (production systems) within the watershed in the eastern area*

considered as rainfed in the LULC cover maps. This is not suitable as rainfed cropping systems are defined in this project and, hence, there is a limited chance that the improvement in rainfed cropping systems could be investigated in these narrow areas.

In the western area, three watersheds were changed from rangeland only to rainfed and rangeland because the cropping systems indicated a significant rainfed area within these watersheds despite low rainfall. Two watersheds were classified for rainfed cropping based on rainfall, but were eliminated when the actual cropping systems within these watersheds were considered because there was a very limited area under rainfed cropping. One watershed was changed from rainfed and rangeland to rangeland only because of the limited rainfed cropping within the watershed (Figure 1.13b). The selected watersheds, based on the rainfall and cropping systems criteria, are shown in (Figures 1.14a and 1.14b).

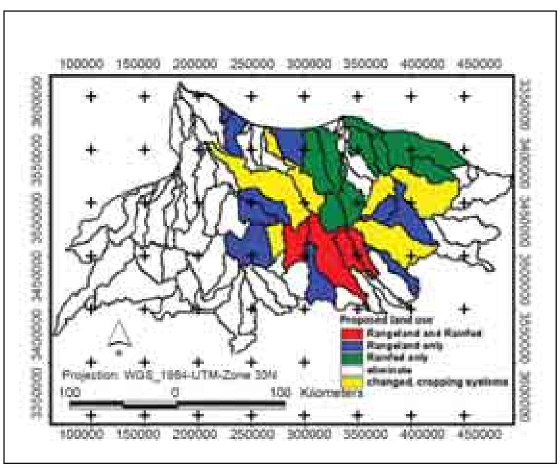


*Figure 1.13b Changing a watershed's intended use based on the availability of sufficient land use (production systems) within the watershed in the western area*

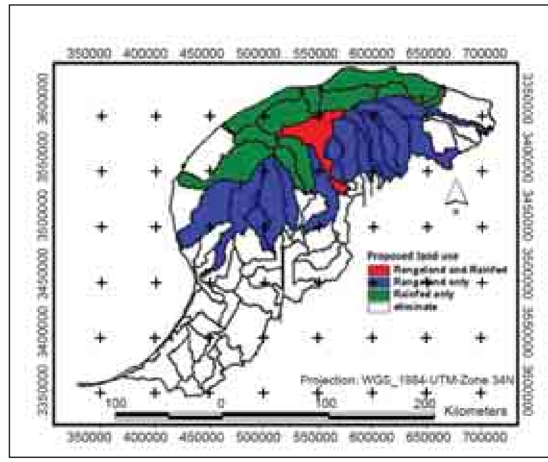


*Figure 1.14a Watersheds selected after applying rainfall and cropping (production) systems criteria in the eastern area*

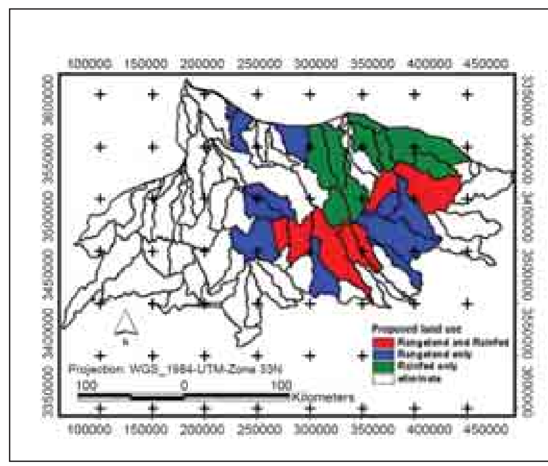


*Figure 1.14b Watersheds selected after applying rainfall and cropping (production) systems criteria in the western area*

### 1.4.3. Communities

The locations of communities (rural settlements) for the whole study area were determined from various sources:

- Topographic maps: these were derived by a previous project
- LULC maps: urban areas, only for major towns and cities, were digitized as part of this mapping
- Satellite images: any settlement that can be seen was digitized. However, this could be only an urban area not a community . A field check during the site visits was necessary
- Google Earth: any settlement that can be seen was digitized. However, this could be only an urban area not a co mmunity. A field check during the site visits was necessary.

The spatial distribution of communities derived from these sources was compiled in one layer. This layer was overlaid on the watersheds to identify the locations of the communities with respect to each of the watersheds selected after applying the rainfall and cropping (production) systems criteria (Figures 1.14a and 1.14b). A proximity analysis (buffer analysis) was applied for the community criteria. This is because the community does not necessarily have to lie within the watershed for the watershed to be considered suitable for the project.

The community can be at certain distance from the watershed and the people of the community still own some land in the watershed. It was decided that the community should be inside the watershed or close to the watershed boundaries – not more than 10 km distant from the boundary. A 10 km buffer area was drawn around each community. Furthermore, the proximity of the communities to the desired activities was also considered as an important factor for the suitability of the watershed for the project. For example, a community should be close to rangeland when rainwater harvesting is being considered. The project required a community to be present to work with – community participation in this project was an important and conceptual requirement. For rainfed areas, the presence of communities was not a limiting factor because most settlements are concentrated in high rainfall areas. However, for rangeland, there are some areas without communities. The criterion of the presence of a community within 10 km of the intended use and within the targeted watersheds was applied. The criterion applied was that communities should be within 10 km if the intended use is for both rangeland and rainfed agriculture, within 10 km if the intended use is for rangeland, and within 10 km if the intended use is for rainfed agriculture.

In the eastern area, all watersheds either included one community inside its boundaries or within 10 km from the boundaries (Figure 1.15). However, five watersheds were eliminated because there were no communities that were close to the area of intended use (Figure 1.16a). The implementation of the project would have been very difficult without the participation of a community. In the western area, three watersheds were eliminated from further consideration because no community was inside or close to the intended area of use (Figure 1.16b).

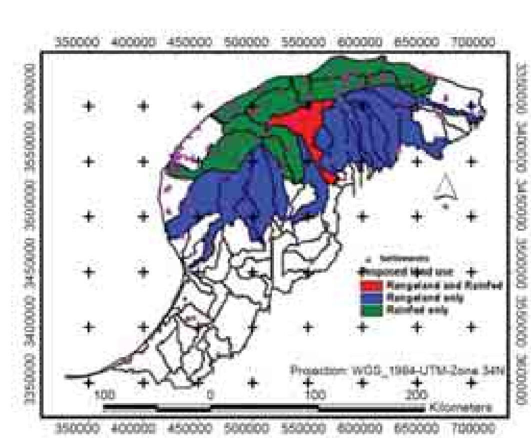


*Figure 1.15 Location of communities inside or in close proximity to watersheds in the eastern area*

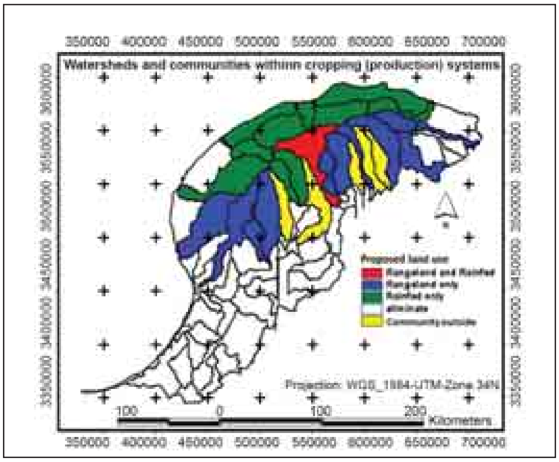


*Figure 1.16a Watersheds eliminate because no community was close to the intended area of use in the eastern area*

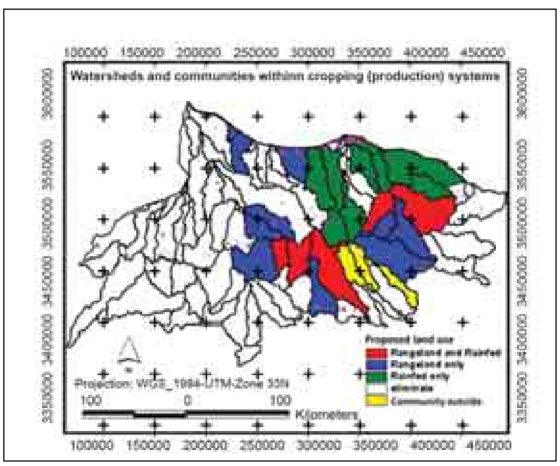


*Figure 1.16b. Watersheds eliminated because no community was close to the intended area of use in the western area*

### 1.4.4. Accessibility and visibility

The road network which was derived from topographic maps (Figures 1.9a and 1.9b) was overlaid with the watersheds selected after applying the criteria of rainfall, cropping (production) system, and communities. Any watershed which is totally disconnected from roads was eliminated because there was little chance of it being accessible and visible to the farming community. In the eastern area, all watersheds were connected to roads and therefore no watershed was eliminated (Figure 1.17a). However, in the western area, three watersheds were eliminated from further considerations because they were disconnected from the road network (Figure 1.17b). Access to these watersheds is not possible and the visibility of the project activities would be very low (may be restricted to just the local community). Furthermore, it was noted that no communities were located within these three watersheds, which makes the implementation of this project impossible in these locations.

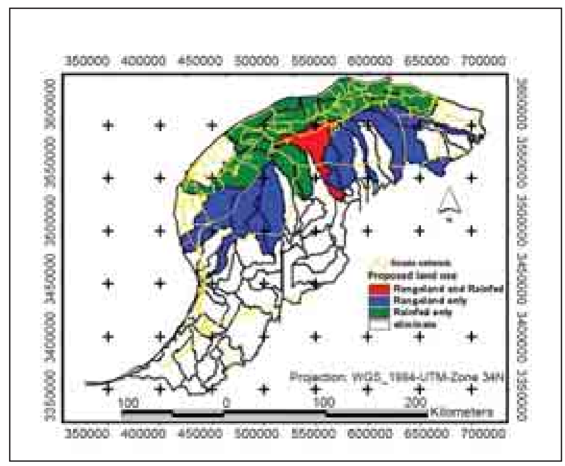


*Figure 1.17a Watersheds and road network (accessibility and visibility) in the eastern area*

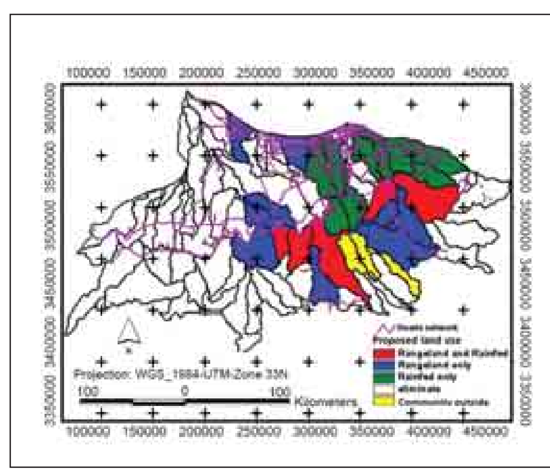


*Figure 1.17b Watersheds and road network (accessibility and visibility) in the western area*

### 1.4.5. Topography

The slope map was classified into three classes (0-10%, 11-20%, and > 20 %) and was overlaid on the watershed boundaries map. The area of each slope class was calculated for each watershed. Most watersheds included enough areas with slope 0-10 % (the best slope class for the project activities). In the eastern area, the smallest area of the class 0-10% was recorded in watershed number 267 – 225 km$^2$. In the western area, the smallest area of the class 0-10% was recorded in watershed number 440 – 147 km$^2$. Therefore, there were no limitations in finding areas of good slope for the project activities.

However, for rainwater harvesting, it is necessary that an area with good slope (less than 10 %) is associated with rangeland areas and not with other land uses. The LULC map was overlaid on the classified slope map and the areas under rangeland and for the different slope classes was calculated for each watershed. Again, most watersheds included enough area with a slope in the range of 0% to 10 % which was used as rangeland. The smallest rangeland area with slope in the class 0-10% was recorded for watershed number 267 (eastern area) – 53 km$^2$. Therefore, there was no limitation to finding rangeland with good slope for rainwater harvesting.

This criterion was further revised after consultation with experts, to estimate the areas with slopes between 0% and 5% and between 6% and 10 % which was, at the same time, under rangeland use. The reason for this further refinement was that some rainwater harvesting techniques are more suitable for slopes between 6% and 10 % than for flatter ones. Some watersheds in the eastern and western areas had limited areas with slopes between 6% and 10 % which were also under rangeland use. These were eliminated because the implementation of various types of rainwater harvesting systems required slopes in the range greater than 5% and less than 10%. Three watersheds were eliminated in the eastern area (Figure 1.18a), and four were eliminated in the western area (Figure 1.18b).

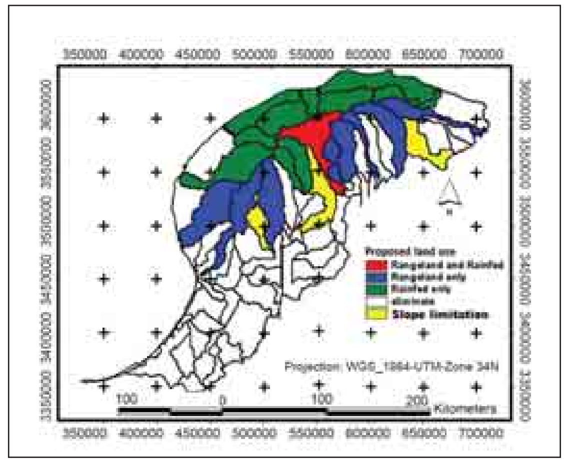


*Figure 1.18a. Watersheds eliminated because of insufficient area with suitable slope for the intended land use in the eastern area*

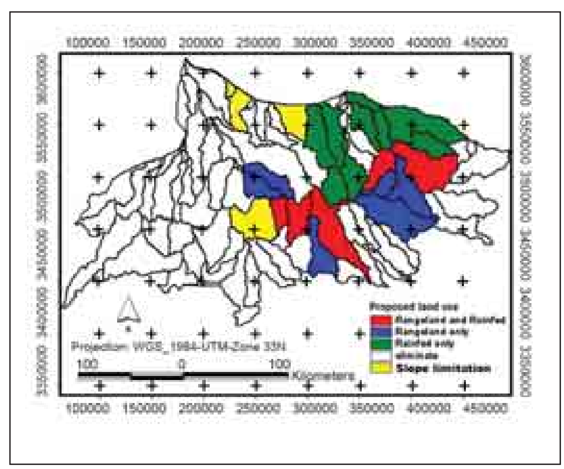


*Figure 1.18b. Watersheds eliminated because of insufficient area with suitable slope for the intended land use in the western area*

### 1.4.6. Soils

The legend of the soil map (1:2,000,000) was used with the keys to the soil taxonomy in order to find the major and secondary limitation(s) of each soil mapping unit. Each mapping unit comprised associations of many soil types. Soil associations for each mapping unit were defined and the keys for the soil taxonomy were used to identify the major limitation(s) of each association. Based on the relative area of each association, the major and second major limitation of each mapping unit were defined (Figures 1.19a and 1.19b).

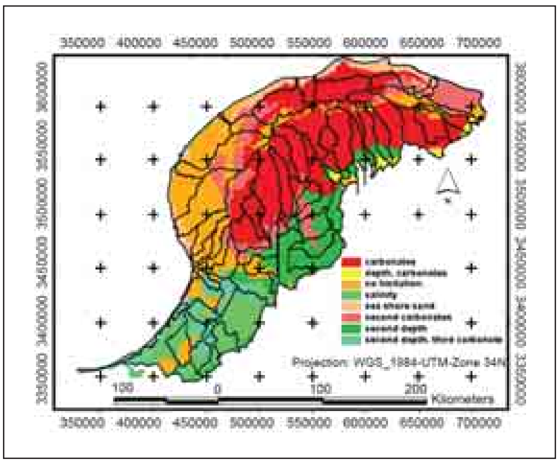


*Figure 1.19a Major limitations of soil mapping units in the eastern area*

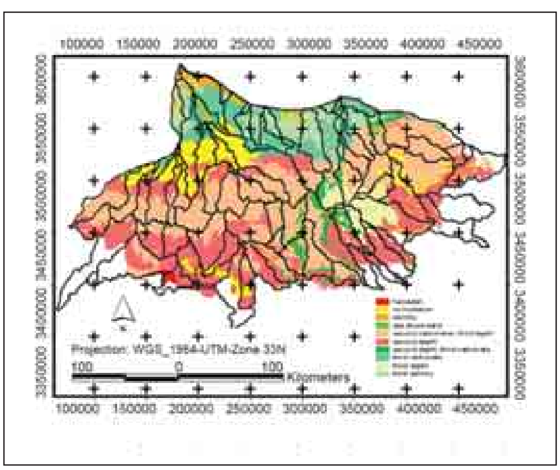


*Figure 1.19b Major limitations of soil mapping units in the western area*

This map was overlaid on the watersheds boundaries map and the area of each soil mapping unit, and consequently the area of limitation(s), was calculated for each watershed. Watersheds with insignificant limitation(s) area within the watershed were eliminated from further considerations. The limitations considered were carbonate concentration, depth, salinity, and sea shore sand content . These might be a major limitation when the dominant soil association is having this limitation as the first limitation or as a second or third limitation when less dominant soil associations are having this limitation. For the eastern area, the dominant limitation was sea shore sand in three watersheds (Figure 1.20a). For the western area the main limitation was salinity for one watershed and sea shore sand for one watershed (Figure 1.20b).

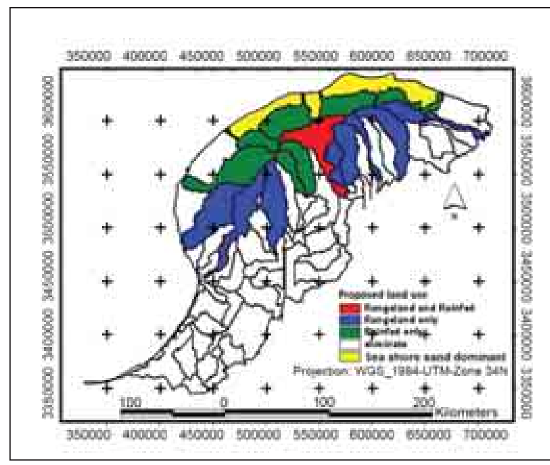


*Figure 1.20a Watersheds eliminated because of limitations imposed by the dominant soil in the eastern area*

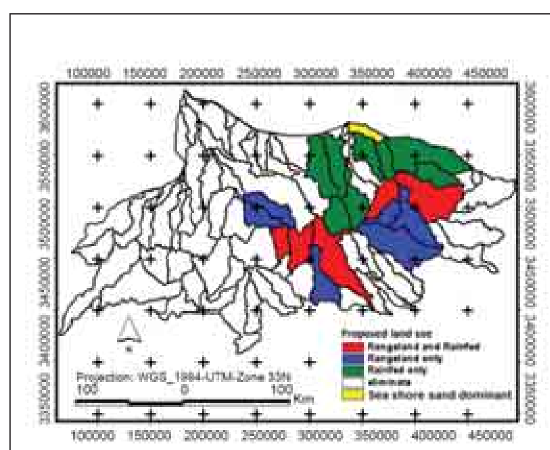


*Figure 1.20b Watersheds eliminated because of limitations imposed by the dominant soil in the western area*

## 1.4.7. Criteria not considered

The following criteria were not considered in the selection process for various reasons:

- Potential for rainwater harvesting: insufficient data was available to permit judgment of this criterion (for example the intensity of the stream network). Therefore, it was decided that it would be better to judge the potential for various rainwater harvesting intervention during the field visits.
- Soil pH: the available soil map, which covers the whole study area, did not contain data to satisfy this criterion
- Small ruminant density: data about this criterion was only available at the *Shaibiat* level (locally known administrative unit in Libya), which was very coarse with respect to the watersheds considered in the selection process. One *Shaibiah* extended over many watersheds and therefore, it was not possible to distinguish individual watersheds based on the density of small ruminants
- Water points: data about water points was available, but the projection of the data was not known. The study area extends over four geographic zones and, therefore, the conversion of this data into a useable format was not possible
- Availability of research stations: the geographic coordinates of research stations were not known and, hence, could not be overlaid with the other GIS data.

Nevertheless, these criteria were considered during the field visits. The observations of the team and the experience of members of the team in the study area were used to judge these criteria and they were incorporated in the final selection.

## 1.4.8. Potential watersheds determination

The above process resulted in a selection of potential watersheds that were earmarked for field visits to judge their suitability for project activities. As a result of applying the above criteria, 16 watersheds were selected in the eastern area (Figure 1.21a) and 18 watersheds were selected in the western area (Figure 1.21b). These watersheds were visited by the inter-disciplinary team of researchers (Appendix B) to select those watersheds that would be used to implement the project.

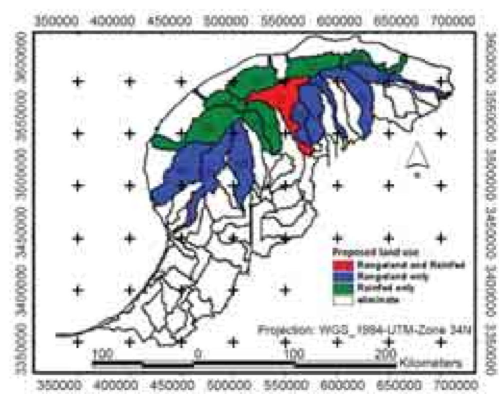


*Figure 1.21a Potential watersheds for field visits after applying the selection criteria in the eastern area*

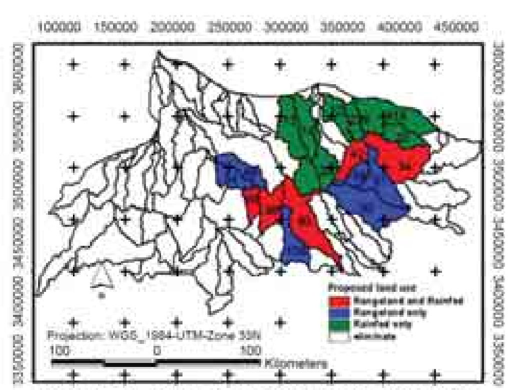


*Figure 1.21b Potential watersheds for field visits after applying the selection criteria in the western area*

## 1.5 Field assessment and final selection

### 1.5.1. Field visits

The inter-disciplinary team undertook a series of field visits during the period July 7-14, 2009. The main purpose was to visit the 16 potential watersheds in the eastern area and the 18 potential watersheds in the western area that had been identified (see previous sections) and to finally select the Integrated Benchmark Research Watersheds (IBRWs). These visits were followed by a report that announced the final selection as made by the researchers from ARC, ICARDA, and other national institutes in Libya.

For navigation, a map sheet was prepared for each watershed as well as an index map for all watersheds. The map layout was printed on A0 size paper and the following layers and information were displayed for each layout:

- Satellite image as background
- Watershed boundaries (based on 50,000 and 25,000 upstream pixels)
- Drainage lines (25,000 upstream pixels)
- Rainfall isohyets
- Roads
- Villages (location and names of all settlements, towns, and communities)
- Coordinates grid, scale bar, north arrow, legend, and watershed number.

The layouts were stored on CD-ROM and copies kept at ICARDA and ARC for future use. The hardcopies were kept at ARC, Libya. An example of these layouts is shown in (Figure 1.22).

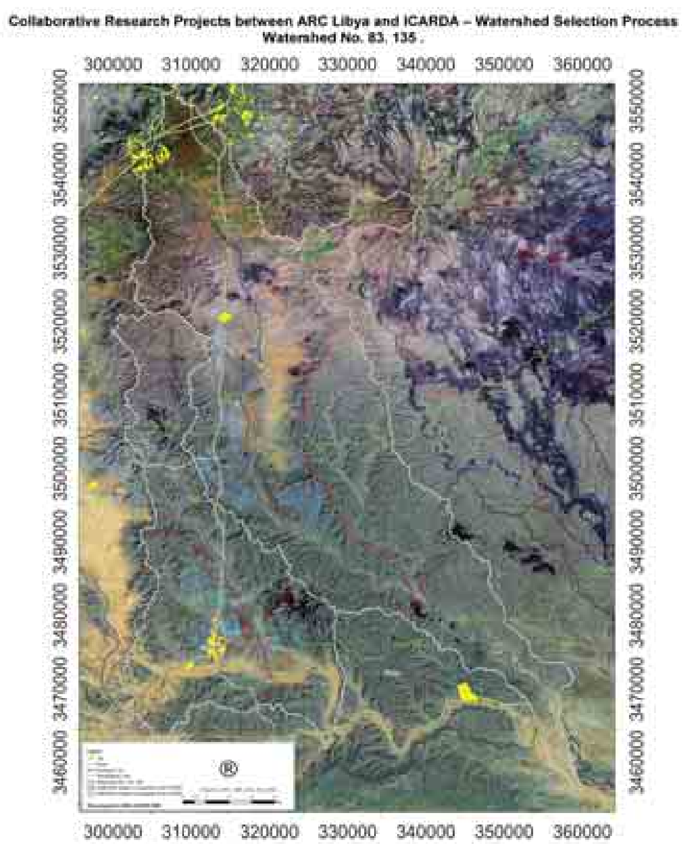


*Figure 1.22 Potential watersheds for field visits after applying the selection criteria in the eastern area*

Each team member was asked to fill in a form about his/her evaluation of the suitability of each watershed for project activities. The form included questions such as the suitability of the watershed for further consideration, the intended use of the watershed (rainfed agriculture, rangeland, or both) and any other helpful comments (Table 1.3). These forms were helpful during the meeting that was held after the visits to discuss the final selection.

After making many stops within the watershed, the team discussed the possibility of working in each watershed. This avoided focusing on localized spots, which might give a wrong impression about the watershed; rather it encouraged looking at the whole watershed after finishing the visit to that watershed.

During four days of field work, the team managed to visit all the potential watersheds. The routes followed during these visits are shown in (Figure 1.23a) for the eastern area and in (Figure 1.23b) for the western area.

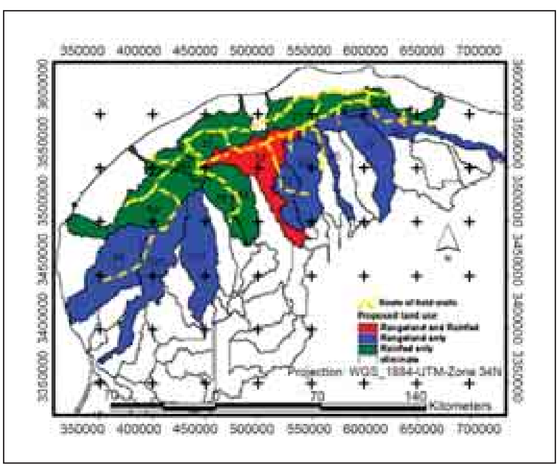

*Figure 1.23a Route followed to cover potential watersheds during the two-day field visits in the eastern area*

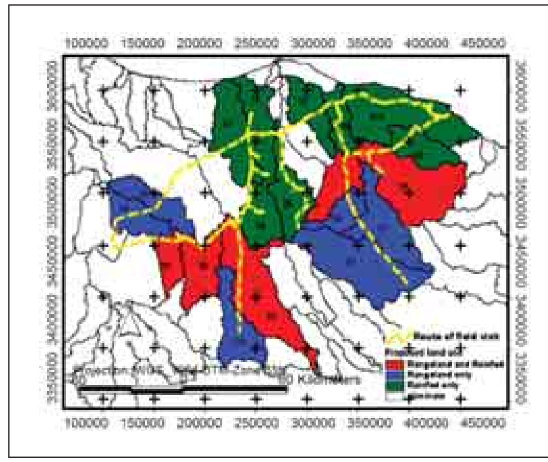

*Figure 1.23b Route followed to cover potential watersheds during the two-day field visits in the western area*

Many stops were made at each watershed and the following aspects were evaluated and discussed by the team after finishing their visit to each location:

- Presence of a community (population density)
- Willingness of community to cooperate (their involvement in agriculture)
- Presence of small ruminants
- Availability and proximity to water points
- Availability and proximity to research stations
- Potential for rainwater harvesting
- Hydrological characteristics of the area
- Safety for research implementation (equipment)
- Land tenure system (use rights and property rights).

***Table 1.3. Field assessment form used by individual team members during the field visits***

| **Name of Evaluator:** | | **Specialty:** | |
|---|---|---|---|
| ***Watershed number*** | ***Consider for further analyses (Yes or No)*** | ***Intended use (Rainfed and rangeland Only rangeland Only rainfed)*** | ***Comments*** |

### 1.5.2. Post field visits meeting and final selection

#### Group meeting for Al-Jabal Al-Gharbi

The team met after the two-day visits to the watersheds and discussed the final ones to be considered for the project activities. In addition to the aspects that were discussed in the field for each watershed, the following issues were highlighted and discussed for the different watersheds:

a. The presence of communities and their potential willingness to participate
b. Accessibility and distance to research stations
c. The soil limitations for some watersheds

The team expressed an obvious preference for three watersheds, which were ranked in terms of their potential from the most desirable to the least desirable (Figure 1.23b):

a. First was watershed no. 83 (Al-Ghadama)
b. Second was watershed no. 99 (Saffeat)
c. Third was watershed no. 416 (Al-Nakaza)
(Table 1.4) shows brief, general features of these watersheds.

#### Group meeting for Al-Jabal Al-Akhdar

In this meeting it was obvious that there were many options to consider. Therefore, the team arranged their opinions in a matrix to express their preferences (Table 1.5).

Watersheds were eliminated, starting with the watersheds with the lowest number of votes. People who voted for the watershed provide their rationale for selecting it. If the characteristics of the watershed were similar to those of other watersheds with a higher number of points, it was eliminated. The final decision was to select four watersheds (table 1.6) in which to undertake the project activities. These were:

a. Watershed no. 37 (Samalos)
b. Watershed no. 58 (Al Qatara)
c. Watershed no. 28 (Al Mualaq)
d. Western part of watershed no.17 (Al Marj)

The watershed location can be seen in (Figure 1.23a). Table 1.6 shows brief, general features of these watersheds.

***Table 1.4. General features of watersheds No. 83 (Al-Ghadama), 99 (Saffeat), and 416 (Al-Nakaza).***

| Watershed no. | Watershed name | Watershed main features |
|---|---|---|
| 83 | Al Ghadama | The watershed is dominated by the three major production systems, rainfed, irrigated, and rangelands. Fruit trees grow in the upper elevations with the higher rainfall, followed by cereal areas and rangelands in the lower elevations of the watershed. The watershed includes several communities and a research station (Gandouba) near the top of the catchment. The watershed drains to the south. |
| 99 | Saffeat | Saffeat watershed is dominated by rangelands and fruit trees with some cereals in the upper elevations of the watershed. It has in it the Saffeat research station and several communities. The watershed drains to the south. |
| 416 | Al Nakaza | Al Nakaza is a large watershed that covers all types of production systems in Al-Jabal Al-Gharbi, including rainfed fruit trees, crops, and rangelands, but it is dominated by trees. When water resources are available, summer irrigation is also practiced. Major communities are settled and many of the indigenous rainwater harvesting systems are located in the watershed. This watershed drains to the Mediterranean sea. |

*Table 1.5. Inter-disciplinary team watershed preferences*

| Name | 37 | 17 | 21 | 58 | 63 | 79 | 239 | 240 | 28 | 30 | 55 | 65 | 73 | 94 | 101 | 103 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Saad | 1 | | | 1 | | | | | | | | | | | | |
| Hussein | 1 | | | 1 | | | | | | | 1 | | | | | |
| Farouq | 1 | | | | | | | 1 | 1 | | 1 | | | | | |
| Karrou | 1 | | | | | | | 1 | 1 | | | | | | | |
| Nowri | 1 | | | 1 | | | | 1 | 1 | | 1 | | | | | |
| Aden | 1 | | | 1 | | | | 1 | | | | | | | | |
| Ali | 1 | 1 | | | | | | | 1 | | | | | | | |
| Saeed | 1 | 1 | | 1 | | | | 1 | 1 | | | | | | | |
| Fawzi | 1 | 1 | | 1 | | | | 1 | 1 | | | | | | | |
| Jumah | 1 | 1 | | | | | | 1 | 1 | | | | | | | |
| Youniss | 1 | 1 | | 1 | | | | 1 | 1 | | | | | | | |
| Adriana | | 1 | | 1 | | | | | | | | | | | | |
| Feras | 1 | X | | | | | | | | | | | | | | |
| Ahmed | 1 | 1 | | | | | | 1 | 1 | | | | | | | |
| Theib | 1 | 1 | | | | | | 1 | 1 | | | | | | | |
| Total | **14** | 7 | 0 | 8 | 0 | 0 | 0 | **11** | **11** | 0 | 3 | 0 | 0 | 0 | 0 | 0 |

1 – select, X – do not agree Red –select, Blue – eliminate

*Table 1.6. General features of watersheds No.37 (Samalos), 58 (Al Qatara), 28 (Al Mualak) and 17 (Al Marj).*

| Watershed no. | Watershed name | Watershed main features |
|---|---|---|
| 37 | Samalos | Marawah watershed extends over the annual rainfall range from over 500 mm to below 100 mm. To a large extent it has the three major production systems, rainfed, irrigated, and rangelands. Fruit trees grow in the upper elevations with the higher rainfall, followed by cereal areas and rangelands at the lower elevations of the watershed. The watershed includes several communities. The watershed drains to the south. |
| 58 | Al Qatara | Al Abyar watershed is dominated by the cereal cropping system, but also has some fruit trees at higher elevations, and rangelands. Communities are cooperative and practice all the production systems. The watershed drains to the Mediterranean. |
| 28 | Al Mualaq | Al Timimi watershed is dominated by rangelands, but has cereals at higher elevations. There are few communities in the watershed. This watershed drains to the Mediterranean. |
| 17 | Al Marj | Al Marj watershed is not a typical one as half of it drains to a depression in the western part while the eastern part drains to the Mediterranean. The group decided to use only the western part where Al Marj station is located so that this production system is investigated. It is a typical rainfed system and suitable for the supplemental irrigation of cereals and other crops. |

## 1.6 Concluding remarks

The whole process of selecting the IBRWs faced many challenges at the beginning. Some of these might be considered as weaknesses, while others are strengths and opportunities that lead to a successful selection process. It was a big challenge to satisfy the diversity of research activities that will be undertaken in one watershed. While the water management group is looking for areas suitable for rainwater harvesting and supplemental irrigation with specific biophysical characteristics, the cereal group is looking for areas with a dominant land use for cereals, and the livestock group is seeking communities with a sufficient number of livestock. Each of these different land uses occur in a unique ecosystem that differ from the others, and the selected watershed is supposed to encompass all of them.

From a biophysical point of view, what also complicates the process is the demand by all groups for certain socioeconomic settings within which these different land uses operate. The project obviously demands a competent community with interest in the research activity under question and with a representative setting that is out-scalable for the whole Libya. Finding a suitable area from the biophysical and socioeconomic points of view was a challenging task. Furthermore, the project components mentioned above are not supposed to work separately, they should work in a fully interactive and integrated mode, with the socioeconomic component as a cross-cutting issue among all other components.

At the beginning of this process and during the first implementation workshop there was a general consensus that the national working groups needed some motivation and awareness raising about two main issues – integrated research sites for different components and the concept of the watershed as a working unit for research activities. Generally, the experience of the national team, although very diverse, long, and rich has been concentrated on individual research sites in terms of location and themes. Therefore, the concept of integrating diverse research activities, such as water management, cereals, livestock, and socioeconomic studies, is a relatively new one. The workshop was successful in highlighting all these deficiencies and helped a lot in formulating the whole selection process. Another new concept that needed introduction and discussion was that of integrating the above components within one watershed and the merit of this approach as compared with selecting many research sites without natural correlation and bindings. However, both parties that advocated the watershed concept and those who were against it were not sure at that stage that they would manage to find watersheds that would satisfy the needs of all components and research groups.

A promising feature that supported the implementation of the selection process is the consensus of all national and international researchers about the challenges that face the agricultural sector in Libya. This highlighted a strong will to change the way agricultural research has been tackled and it was very obvious that business as usual was not an option if a sustainable research strategy is to be formulated for integrated work.

Previous experience demonstrated many research activities, but, in most cases, this was scattered among various themes and locations. This was highlighted as a reason for the poor integration of research efforts in the agricultural sector, which provided support for this selection process.

Another source of support for the selection process was the availability of data about most biophysical features in the study area, especially in areas where the annual rainfall exceed 200 mm. The 'agricultural regions' study, which was finished just before the start of the selection process, provided a lot of support in the selection of promising study areas where the project would be successful. The experience of the national team and their knowledge about available relevant data was indispensable to the success of this process. One important feature of the selection process is the integration of various disciplines through the interactive participation of an inter-disciplinary team of researchers throughout the various stages of this process, from defining selection criteria, through data collection, analyses, field visits and final selection. This was supported by full utilization of GIS and remote sensing capabilities to undertake the compilation, harmonization, integration, and analysis of spatial and non-spatial data. An important feature of this is the flexibility of the approach to include data from various sources, as well as the possibility of including local experience and knowledge whenever possible and relevant. The iterative nature of the process enables the adjustment of different criteria and their application to reach acceptable results that match the ground.

The sequence of analyses followed during the selection proved successful. It started by defining the selection criteria, applying the criteria, analyzing the data, presenting the results to the team, and appropriately manipulating the criteria. This process was repeated through various iterations and finally confirmed by the results by field visits. A final selection was then agreed. The approach seems very flexible, but it sticks to fixed criteria and rules that were agreed by the whole team.

The success of the approach followed was judged using different aspects. The final voting pattern of the team indicated the agreement between the results achieved after applying the criteria and the characteristics of the watersheds as assessed during the field visits. In particular, the allocation of the different watersheds to the categories of 'rainfed only', 'range only', or 'both rainfed and range', following the field visits, shows good agreement. The experience of the national team indicated that the watersheds selected after applying the criteria were areas of good potential in which to implement the project. Judgments, based on their experience, indicated that the process guided them to the areas that best represent the rainfed, range and livestock activities. They expressed their satisfaction at finding these areas located within one watershed. They were able to determine the boundaries between watersheds based on their knowledge on the ground.

Another encouraging result that indicates the success of the approach is the clear agreement among the team members in reaching the final selection of the watersheds. The task was very easy and straight forward in the western area given the clear subdivision of rainfed and range areas. In the eastern area, the task was more difficult because of the high diversity among cropping (production) systems. However, a clear consensus was reached among the team members on a limited number of watersheds. Through the discussion, the team very easily arrived at agreement about the final selection of watersheds. It was very encouraging to find one watershed in the eastern area (Samalous watershed) and one watershed in the western area (Ghadama watershed) where both rainfed and rangeland are abundant and located within one watershed. This was a basic requirement for the project implementation. Except for one team member, the whole team voted for these two watersheds as the best ones in which to achieve the project's goals.

These achievements are very important for the project at this early stage where the integration of various components is very important. Beyond this, the process managed to present results in a way that will be useful in the future for any integrated research activities and wherever watershed selection is needed. The approach is reproducible whenever the process is needed for different research activities; the criteria can be modified and the whole process repeated to reach an acceptable result. The capacity building component was very important and the team was trained to undertake the process. Thus, the benefits of the selection process presented go beyond the immediate achievement of selecting watersheds that were confirmed by the majority of the team members. It is anticipated that the selected watersheds will enable researchers to undertake integrated research activities that contribute to the improvement of agriculture at both national and regional levels.

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