DEVELOPING AN INTEGRATED HYDRO-AGRICULTURAL DEVELOPMENT PLAN:

CAZA OF MARJEYOUN - LEBANON

GUIDELINES FOR THE RECLAMATION WORKS

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By the
CIHEAM - Mediterranean Agronomic Institute of Bari
Table of Contents

INTRODUCTION

1 – THE GREEN PLAN EXPERIENCE
   1.1 – Green Plan Table of Costs
   1.2 – Land Reclamation Works
   1.2.1 – Main Works
   1.2.2 – Complementary Works

2 – OTHER PARAMETERS TO CONSIDER FOR TERRACING
   2.1 – Optimal Width and Height of Terraces
   2.2 – Depth of Productive Soil

3 – LAND CLASSIFICATION DETAILS

4 – GUIDELINES FOR LAND RECLAMTION COSTS ESTIMATION
   4.1 – Main Works
   4.2 – Complementary Works

5 – MAIN WORKS DESIGN AND EXECUTION GUIDELINES
   5.1 – Case of Existing Terraces
   5.2 – New Terraces
       5.2.1 – Terrace Vertical and Horizontal Intervals
       5.2.2 – Types of Terraces
   5.3 – Common Works

6 – COMPLEMENTARY WORKS GUIDELINES
   6.1 – Wall construction
   6.2 – Cleaning from Stones and Pebbles

ANNEXES
INTRODUCTION

“The art of terracing is nearly as old as farming itself considered as a vital part of many ancient civilizations”1. In many Mediterranean countries, including Lebanon the remains of the ancient terraces in mountainous and hilly areas are evidence verifying this theory.

“...In the last 6 decades, land leveling and terracing has gained an important role in European agriculture. The acreage of rain fed crops such as almonds, vines and olives have been expanded rapidly even in marginal areas, encouraged by policies simulated by the EU. For instance, land terracing was accelerated after the introduction of the EU Council Regulation policy for vineyards in 2000 in which the construction cost of terraces was subsidized up to 50%2.

In Lebanon, the Green Plan, a technical autonomous directorate under the ministry of Agriculture, was created in 1965 to help farmers with land reclamation. Besides the construction of rural roads, pounds and water reservoirs, one of its main activities regarded terrace construction. Before 1975, the Green Plan subsidized the reclamation works executed with heavy machinery by more than 85%. However, after 1990, a drastic decrease of budget limited its activity.

The general geomorphology of Southern Lebanon shows hilly lands with a great need for reclamation before any development project is implemented. In the case of the “Integrated Hydro Agriculture Development Plan: Caza of Marjeyoun” project, the main land reclamation works will be executed and relative costs supported by the project. Nevertheless, the long experience of the Green Plan remains the principal reference for land reclamation works to be executed. Moreover, other experiences or studies would be considered if they add any new concept to ameliorate the Lebanese experience in this field. In addition, the land classification developed by the project which describes the principal characteristics and calculates the main parameters that would affect reclamation works in the area, will also be a valuable reference for land reclamation works design.

1 – THE GREEN PLAN EXPERIENCE

1.1 – Green Plan Table of Costs

The objective of the Green Plan is to help farmers improve their income by extending the productive area. Lands with slopes lower than 40% and with a percentage of rock outcrops lower than 60% are qualified for receiving the subsidy. However, special cases where the percentage of rocks is lower than 10% and slopes are higher than 40%, can be considered as well.

The works’ related costs consider the following parameters:
- The natural slope.
- The nature and percentage of rock outcrops at the surface.
- The terracing works.

1.2 – Land Reclamation Works

1.2.1 – Main Works

These works are executed with heavy machinery like bulldozers: Cleaning

Before and after the execution of reclamation works, land surface must be cleaned from vegetation, rocks, stones and pebbles. This step can be executed with bulldozers.

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1 Traditional and new soil conservation and cultivation structure Booklet published by LUCINDA (EU project) by C.Kosmas, N.Yassoglou, A. Kounalaki and O. Kairist (Agricultural University of Athens).

2 Idem
**Removing top soil**
The fertile top soil is removed either laterally or laterally and longitudinally with bulldozers to prevent its reversing with infertile subsoil. After the execution of all works, the soil will be replaced on the top.

**Using the Ripper**
The ripper can reach more than one meter in depth; it helps removing and cutting soft rocks and hard cracked rocks. Many parcels of the considered area are fallow lands and need a deep plow.

**Terracing**
The main purposes of land terracing can be summarized as follows:
- Redistribution of soil material in sloping areas with shallow or moderate soil depth.
- Increasing of plant root depth to enhance nutrients and water absorption by the plant.
- Reducing the steepness of sloping lands, improving access and facilitating farm operations.
- Cleaning fields from stones which can interfere with cultivation.
- Decreasing surface runoff and increasing water infiltration after heavy rainfall events.
- Controlling soil erosion in sloping areas.

In addition to the previous works, excavation, rocks removing and cleaning, embankment and leveling are needed for terracing.

As previously explained, the maximum slope allowed for terrace construction is 40%. Exception is made for lands with a percentage of rocks in surface lower than 10% if the following conditions are fulfilled:
- the retaining wall has a minimum width of four meters and a maximum height of two meters.
- the slope doesn’t exceed 50%.

An FAO study identifies three classes among the existent terraces in South Lebanon according to the nature of subsoil rock and the type of soil as shown in the following table:

<table>
<thead>
<tr>
<th>Subsoil Rock</th>
<th>Type of Soil</th>
<th>Terraces Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard slight cracked Rocks</td>
<td>Non-calcareous red soils</td>
<td>Terraces with terraces walls (Stones)</td>
</tr>
<tr>
<td>Hard cracked Rocks</td>
<td>Non-calcareous red soils</td>
<td>Terraces with bank of stones and pebbles</td>
</tr>
<tr>
<td>Soft Rocks – Marls</td>
<td>Grey soils very calcareous</td>
<td>Terraces with grassing bank</td>
</tr>
</tbody>
</table>

This classification is in compliance with the rocks’ classification adopted by the Green Plan. The shape of the terraces is reported in Annex 1.

**Leveling**
This technique is used to give to the parcel a regular, flat surface or a low, regular slope. This work is executed with bulldozers.

**1.2.2 – Complementary Works**
Not supported by the Green Plan and they are the sole responsibility of the farmer. They include:

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4. Enquête pédologique et programmes d’irrigation connexes- Liban fao /sf : 51/leb-10
**Walls construction**
Walls shall be constructed with dry stone. The average thickness of the wall should be the half of its height with a minimum coronation of 0.5 meter as it would be exposed to damage. Trapezoidal section is such as to ensure an inclination of 10 to 30% of the outer wall side.

**Stones and Pebbles Cleaning**
It consists of removing stones and pebbles. In stony and pebbly soils, this will be a permanent exercise to be executed by the farmer after each deep ploughing.

2 – OTHER PARAMETERS TO CONSIDER FOR TERRACING:

2.1 – Optimal Width and Height of Terraces

The U.S. Soil Conservation Service proposes the following formula to determine the best vertical interval (VI in meters):

\[ VI = XS + Y \]

Where X is a rainfall factor, S is the slope gradient (%) and Y the soil and cropping factor. The U.S. Soil Conservation Service recommends values for x and y of 0.12-0.24, and 0.3-1.2, respectively. If soil is particularly impermeable and the crop provides little cover, then the value 0.3 is used for y; 0.75 is selected if either the soil or the crop favors soil erosion control. The value 1.2 is used for permeable soil combined with adequate crop cover.

The horizontal interval (HI in meters) can be calculated from the equation:

\[ HI = (VI/S) \times 100 \]

The horizontal interval on manually cultivated land can be considerably narrower than the one would be used for mechanized agriculture.

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5Traditional and new soil conservation and cultivation structure Booklet published by LUCINDA (EU project) by C.Kosmas, N.Yassoglou, A. Kounalaki and O. Kairist (Agricultural University of Athens).

6Idem
2.2 – Depth of Productive Soil
The productivity of irrigated terraces is very important as it determines the feasibility of an irrigation project. Productivity mainly depends on soil depth, a crucial parameter for the design and execution of terracing works.

Terrace spacing is normally expressed in terms of vertical intervals between two terraces. It depends on soil, slope, surface condition, grade and agricultural use (See section 2.1. Optimal width and height of terraces).

The vertical interval depends on the depth of the cut. Since the depth of the cut and the fill are to be balanced, \((VI)\) is equal to the double of the cut depth\(^7\). To calculate the dimensions of the terraces the following parameters are needed:
- The maximum depth of productive soil;
- The maximum admissible cutting depth—\(D/2\) or \(d\);
- The land slope, \(S\).

As a result, the width of the terraces \(W\) can be computed for a given slope \(S\) using the following formula:

\[
W = \frac{200d}{S}
\]

The soil productivity of the terrace is improved if topsoil is removed, stockpiled, and later spread over the terrace after the construction phase completion.

3 – LAND CLASSIFICATION DETAILS
The classification methodology of the soil suitability for irrigation is based on the geomorphology and the soil characteristics that influence the cost of land reclamation as well as soil productivity\(^8\).

The soil characteristics influencing yield and land reclamation costs are:
- Soil depth;
- Land natural slope;
- Nature of the rock outcrop and the percentage of the rock coverage;
- Percentage of stones in surface;
- Percentage of pebbles and gravels in surface;
- Nature of Horizon A;
- Soil texture and percentage of pebbles and gravels in the profile at the depth of:
  - 0 to 20 cm
  - 20 to 50 cm
  - > 50 cm
- Rehabilitation or renovation of existing terraces according to the type of terrace. The type depends on the shape, width and actual status (Annex 1).

The combined annual revenue and annuity of land reclamation costs determine the net revenue per hectare. Consequently, lands are classified according to their net revenue which is the ability for irrigation. Annex 2 shows all the parameters used for land classification.

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\(^7\)My information Agricultural Bank- Watershed Management
\(^8\)Updating the Detailed Land Classification Methodology for suitability to irrigation
4 – GUIDELINES FOR LAND RECLAMATION COSTS ESTIMATION

The feasibility of land reclamation works is guaranteed in the case of the “Integrated Hydro Agriculture Development Plan: Caza of Marjeyoun” as works will be executed for irrigable classes. As mentioned before, the classification is based on economic parameters.

4.1 – Main Works
The table of costs established by the Green Plan can be adopted as a maximal shape for works costs. The empirical table of costs (Annex 1), is the result of a long experience in land reclamation.

An analysis of this table summarizes the main costs by the means of a simple formula based on a unit cost “K”. The updating of costs becomes a simple exercise:

In the first case (slope > 10%):

\[ C = K(50 + 2(S - 10) + R + 10N + 20T) \]

In the second case (rocks’ percentage < 10%):

\[ C = K(50 + (S - 10) + R + 10N + 20T) \]

Where \( C \) is the Total cost in Lebanese Pounds, \( K \) the Unit cost, \( S \) the Natural Slope, \( N \) the Nature of Rocks (\( N=0 \) for Soft or Hard cracked Rocks) and \( T \) the Existing Terracing Works (\( T=0 \) if No Terracing works; \( T=1 \) for Existing Terracing Works).

4.2 – Complementary Works

Terraces Walls

Surface Cleaning

5 – MAIN WORKS DESIGN AND EXECUTION GUIDELINES

5.1 – Case of Existing Terraces
The existing terraces can be classified into four types as for their reclamation needs (Annexes 3 and 4 report on the classification method of the existing terraces):

1 - No rehabilitation is required.
2 - Some rehabilitation work is required at retain wall level: the rehabilitation cost is estimated as 15% of the total cost of a retain wall on lands with same slope.
3 - Some overall rehabilitation work is required: the rehabilitation cost is estimated as 25% of the total cost for reclamation of a land with the same slope.
4 - Total reconstruction is required.

5.2 – New Terraces

5.2.1 – Terrace Vertical and Horizontal Intervals
Many parameters affect the design of terraces as shown in previous sections. Given that terracing will serve an irrigation project, the adopted irrigation techniques should be considered.

In Marjeyoum project, the irrigation system is pressurized. Possible techniques are trickle and sprinkler. The latter is more requiring in terms of slope limitation (up to 8%) and terrace width (multiple of 6 meters).

Calculation of Optimal Height and Width (U.S. Soil Conservation Service formula)
Using the formula \( VI = \frac{XS}{Y} \) (See section 2.1. Optimal width and height of terraces), the calculation of Height and Width for Marjeyoun area gives the results shown in Annex 5.

Soil-related parameters considered in the calculation are: \( Y=0.3 \) for clay soils and \( Y=0.75 \) for moderately permeable soils. Two values (0.12 and 0.24) are considered for the Rainfall factor \( X \).

**Productive Soil Depth** *(see section 2.2. Depth of productive soil)*

The most productive soil in the region is more than 1 meter deep (\( d=1 \)) and then \( D=2 \) meters can be considered. In case of vertical terrace cuts with similar triangles, the formula \( W = \frac{200 d}{3} \) is applied. The maximum allowable widths by slope are given in Annex 6.

**Results**

Considering that:
- Lands with a slope lower than 8% don’t need terracing;
- Irrigated terraces widths must be multiple of six;

and accounting for the results obtained by applying the adequate formulas where width and depth of productive soil are considered, the allowable terracing works are given in the following table.

The Maximum allowable Vertical Interval is 1.92 meters very close to the Allowable Height by the Green Plan (2 meters).

**Table 2: Characteristics of allowable terracing works**

<table>
<thead>
<tr>
<th>Soils Types</th>
<th>Interval in Meter</th>
<th>Slope in %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Horizontal (HI)</td>
<td>8 15 20 30</td>
</tr>
<tr>
<td>Slow permeable Soils</td>
<td>18 12 6 6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>24 12 6 6</td>
<td></td>
</tr>
<tr>
<td>Moderate Permeable Soils</td>
<td>18 12 6 6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>24 12 6 6</td>
<td></td>
</tr>
<tr>
<td>Slow permeable Soils</td>
<td>1.44 1.8 1.2 1.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.44 1.8 1.2 1.8</td>
<td></td>
</tr>
<tr>
<td>Moderate Permeable Soils</td>
<td>1.44 1.8 1.2 1.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.44 1.8 1.2 1.8</td>
<td></td>
</tr>
</tbody>
</table>

5.2.2 – Types of Terraces

(Refer to tab. 1 for possible types of terraces)

Apart from what it has been specified in Table 1 about the nature of rocks in subsoil and type of soil, an additional condition should be respected for the construction of terraces with walls: The availability of material in the land (See section 6.1. Terraces wall construction). Walls construction could become very expensive and non-feasible if the farmer has to import material from outside the land as the price of stones and transportation should be added to the total cost.

5.3 – Common Works

These works are described in section 1.2.1. Following are the main works as they are usually executed by the Green Plan in chronological order:
- Surface cleaning
- Topsoil removal and stockpiling
- Topsoil spreading over the terrace at the construction phase completion
- Ripper ploughing with rocks removing
- Terracing with excavation, rocks removing and cleaning, embankment
- Leveling

6 – COMPLEMENTARY WORKS GUIDELINES

6.1 – Wall construction

Five factors affect the cost of construction of retaining walls: the natural slope of land, the percentage of rock outcrops on the surface, the percentage of stones on the surface, the percentage of pebbles and soil depth. The last four factors determine the feasibility of walls construction:

- The percentage of surface rocks can be estimated as a function of soil depth; the overall volume of available rocks is estimated as building material for walls.
- The pebbles are elements with dimensions between 7.5 and 25 cm and the stones are elements with dimensions greater than 25 cm; the available amount of walls building material can be estimated from their respective percentages.
- From the foregoing, it would be possible to estimate the total amount of available material (AM) for walls construction. This sum will be expressed as follows:

\[ AM = D \times R + S \times 0.5 + G \times 0.25 \times 0.25 \]

Where:
R = Percentage of rocks surface outcrops
D = Depth of soil
S = Percentage of stones in surface (the average size of stones is estimated to 50 cm)
G = Percentage of gravels in surface.

Accounting for the slope and for the conditions set above, the section of the wall can be determined and the volume of the material needed for its construction could be estimated (Annex 7).

Only when the total volume of rocks and stones is equal to or greater than the volume of material required for construction, this operation would be possible.

6.2 – Cleaning from Stones and Pebbles

It consists of picking up stones and pebbles by workers and transporting them by tractor.
ANNEXES
**Anex 1:** Types of existing terraces in South Lebanon

<table>
<thead>
<tr>
<th>Type of Soils</th>
<th>Type of terraces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard slight cracked Rocks</td>
<td>Terraces with terraces walls (Stones)</td>
</tr>
<tr>
<td>Non-calcareous red soils</td>
<td>Terraces with grassing bank</td>
</tr>
<tr>
<td>Hard cracked Rocks</td>
<td>Terraces with bank of stones and pebbles</td>
</tr>
<tr>
<td>Non-calcareous red soils</td>
<td></td>
</tr>
<tr>
<td>Soft Rocks – Marls</td>
<td></td>
</tr>
<tr>
<td>Grey soils very calcareous</td>
<td></td>
</tr>
</tbody>
</table>

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9 ENQUETE PEDOLOGIQUE ET PROGRAMMES D'IRRIGATION CONNEXES- LIBAN FAO /SF : 51/LEB-10
### Annex 2: Land Classification Sheet for Field Investigation

**Hydro Agricultural development project for Marjeyoun Area**  
Field Prospection of Detailed Land Classification

<table>
<thead>
<tr>
<th>Cadastral District</th>
<th>Plan Number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parcel Number</th>
<th>Area in Square Meter</th>
<th>Soil Depth</th>
<th>Texture</th>
<th>Texture</th>
<th>Texture</th>
<th>Horizon A</th>
<th>Surface Elements in %</th>
<th>Existent Terraces</th>
<th>Crops</th>
<th>Ability for Irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 - 20 cm</td>
<td>20 - 50 cm</td>
<td>&gt;50 cm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1/20,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pebbles and gravels &lt;2 mm</td>
<td>Pebbles and gravels &lt;2 mm</td>
<td>Pebbles and gravels &lt;2 mm</td>
<td>Slope</td>
<td>Rocks</td>
<td>Stones</td>
<td>Pebbles and gravels</td>
<td>Form</td>
</tr>
</tbody>
</table>

10 Updating the Detailed Land Classification Methodology for suitability to irrigation
### Annex 3: Class of characteristics of existing terraces\(^{11}\)

<table>
<thead>
<tr>
<th>Class</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shape</strong></td>
<td>Flat and regular</td>
<td>Slope transverse and regular</td>
<td>Regular longitudinal slope</td>
<td>Irregular and flat</td>
<td>Irregular buckled</td>
</tr>
<tr>
<td><strong>Status</strong></td>
<td>Walls in a good state</td>
<td>Walls in bad state</td>
<td>Bank in good state</td>
<td>Bank in bad state</td>
<td></td>
</tr>
<tr>
<td><strong>Width in Meter</strong></td>
<td>&lt;4</td>
<td>&gt;4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Annex 4: Terraces classification according to the Shape, State, and Width\(^{12}\)

<table>
<thead>
<tr>
<th>Status</th>
<th>Width</th>
<th>Shape</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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</thead>
<tbody>
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<td>1</td>
<td>4</td>
<td>4</td>
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<td>4</td>
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<td>4</td>
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<td>4</td>
</tr>
</tbody>
</table>

### Annex 5: Calculated Height and widths by U.S. Soil Conservation Service

<table>
<thead>
<tr>
<th>Formula Parameters</th>
<th>Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>8</td>
</tr>
<tr>
<td>0.12</td>
<td>1.26</td>
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<tr>
<td>0.24</td>
<td>2.22</td>
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<tr>
<td>0.12</td>
<td>1.71</td>
</tr>
<tr>
<td>0.24</td>
<td>2.67</td>
</tr>
<tr>
<td>Height terrace or Vertical Interval in Meters</td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>15.8</td>
</tr>
<tr>
<td>0.12</td>
<td>27.8</td>
</tr>
<tr>
<td>0.24</td>
<td>21.4</td>
</tr>
<tr>
<td>0.24</td>
<td>33.4</td>
</tr>
<tr>
<td>Terrace Width or Horizontal Interval in Meters</td>
<td></td>
</tr>
</tbody>
</table>

### Annex 6: Maximum allowable width by slope value

<table>
<thead>
<tr>
<th>Slope</th>
<th>8</th>
<th>15</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
</tr>
</thead>
</table>

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\(^{11}\)Updating the Detailed Land Classification Methodology for suitability to irrigation  
\(^{12}\)Ibid  
13 Irrigation Water Management – Irrigation Methods - FAO
<table>
<thead>
<tr>
<th>Allowable width</th>
<th>25</th>
<th>13.3</th>
<th>10</th>
<th>6.67</th>
<th>5</th>
<th>4</th>
</tr>
</thead>
</table>

**Annex 7:** Volume of material required to build the walls in m³ ha⁻¹

<table>
<thead>
<tr>
<th>Slope value in %</th>
<th>8-15</th>
<th>15-20</th>
<th>20-30</th>
<th>30-40</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume by Class</td>
<td>630</td>
<td>1000</td>
<td>1500</td>
<td>2450</td>
<td>5000</td>
</tr>
</tbody>
</table>