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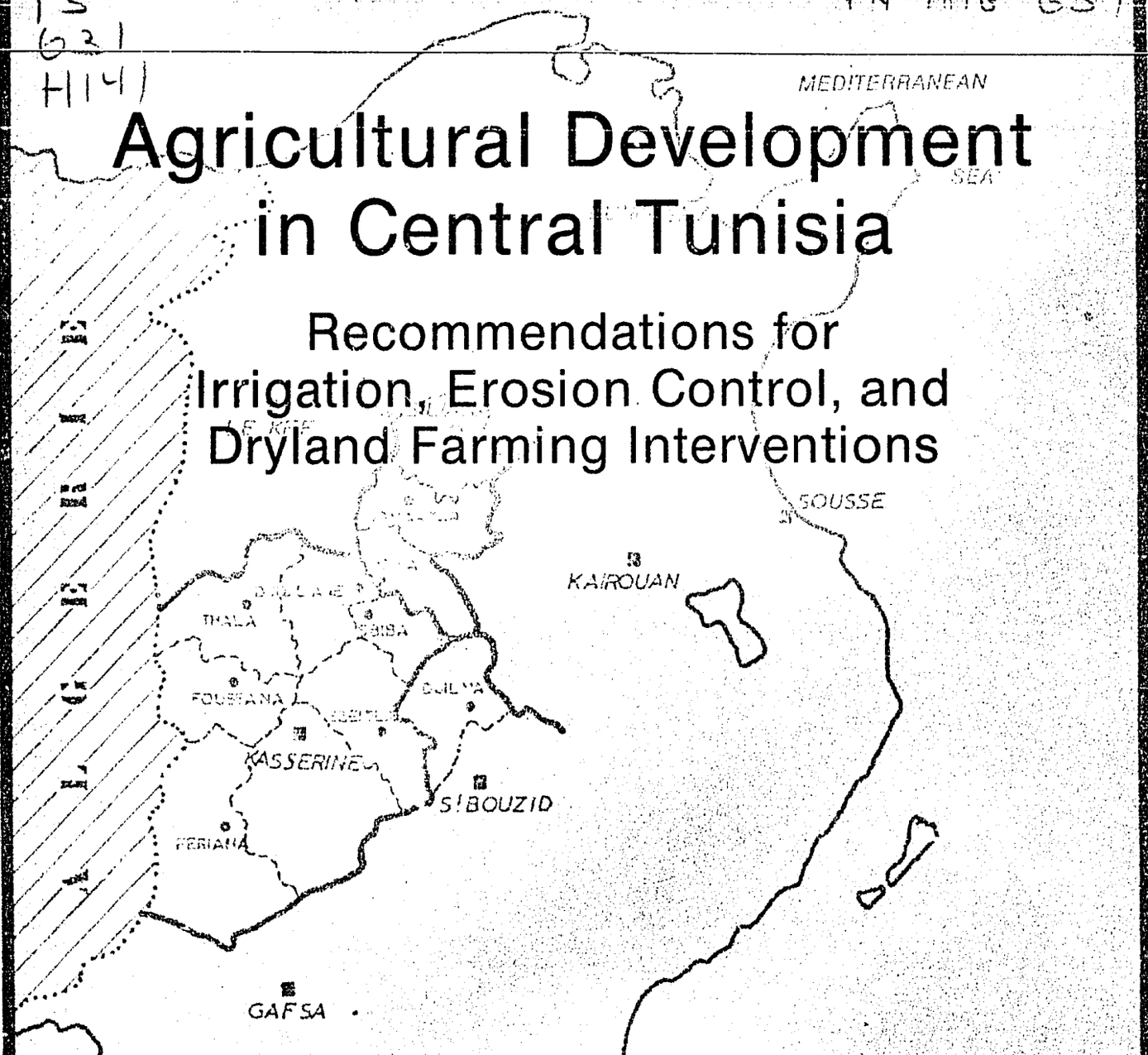
Recommendations for Irrigation, Erosion Control, and Dryland Farming Interventions



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PREFACE

Organization of Report

This report summarizes work completed in Tunisia during June and July in connection with the Central Tunisia Rural Development project. As later explained in the introduction, this assignment resulted from earlier work by a University of Missouri consulting team which prepared an assessment of the agricultural potential of the eight delegations of the project area.

Since this report contains rather detailed recommendations for the four major interventions included in the assignment, several steps have been taken to make it more readable.

First, a brief summary of the highlights and recommendations is included at the beginning of the report. This is followed by an introductory chapter which includes a brief description of the resources and problems in the project area and a summary of the specific objectives of the current assignment.

Then, one chapter is devoted to each of the four major interventions assigned, with a rather detailed outline of each in the table of contents. A final chapter consists of suggestions for economic evaluations, budget estimates, and qualifying conditions precedent to implementation.

An appendix section is correlated with each chapter of the report, preceded by an index page which itemizes the content of each.

As a further aid to more convenient references, each paragraph is numbered by chapters in the body of the report.

Acknowledgments

Members of the consulting team are grateful for the many courtesies and types of assistance provided by members of the USAID Mission staff, of the Ministry of Agriculture and its various divisions, and of other related agencies. Dr. Herman S. Davis, Jr., Dr. Carl Ferguson, Dr. Doug Butchart, Dr. Patrick Demongeot, and other members of the Mission staff were especially helpful in providing facilities as well as advice and suggestions for the conduct of the assignment. The help of Mrs. Elke El Abed with day-to-day arrangements and of Mrs. June Parker in typing and assembling the first draft of this report was greatly appreciated. Members of the USDA PASA team, working on various phases of the livestock and forage improvement projects, also shared many useful experiences and information with team members.

John Blackton, USAID/Washington, and Stanley Peek, USAID Consultant, took time to proof-read the first draft of the report and to discuss the recommendations. Their comments and suggestions for revisions were greatly appreciated.

Numerous personal conferences and meetings with staff members of different divisions of the Ministry of Agriculture provided valuable insights relative to feasibility of proposals for the project area. They included Mr. Abdelmajid Slama, CNEA; Mr. Lasram, INRAT; Mr. Hezim, SCS; Mr. Abdel Hafid Jabeur, OMVVM and Director of the Office for the project area; and directors and staff members of other divisions such

as DRES, INAT, and the Office of Cereals. Dr. Daaloul, director of the College of Agronomy of Lekef, Moncif Harrabi, and Habib Halila were especially helpful with developing proposals for applied research in the project area.

Appreciation also is extended to Peter J. Reitz and Tom Kopf of the Care-Medico staff in Tunis and associated Peace Corps volunteers, for sharing their experiences with well improvement projects in the Central Tunisia area and for other valuable assistance.

All of the above contributed to an enjoyable and rewarding experience for team members during their short stay in Tunisia.

LIST OF ACRONYMS

Numerous acronyms are used in Tunisia for referring to various institutions and agencies. Those most relevant to this report are alphabetized and defined below:

1. BIRH --Hydraulic Resources Inventory Bureau
2. BNA --National Agricultural Bank
3. BNT --National Bank of Tunisia
4. BPDA --Planning and Development Office
5. CCSPS --Central Cooperative for Seeds & Selected Plants
6. CES --Soils and Water Conservation
7. CLCM --Local Mutual Credit Fund
8. CNEA --National Center of Agricultural Studies
9. COCEMO --Central Cooperative of Mechanized Farming
10. CRDA --Regional Center for Agricultural Development
11. CTRD --Central Tunisia Rural Development
12. DAFL --Land Tenure and Legislation Office
13. DPA --Division of Agricultural Production
14. DRES --Water and Soil Resources Directorate
15. FAO --Food and Agriculture Organization of the United
16. FOSDA --Special Funds for Agricultural Development
17. GOT --Government of Tunisia
18. GR --Rural Engineering Service
19. IBRD --International Bank of Reconstruction and Development (World Bank)
20. INAT --National Institute of Agronomic Teaching
21. INRAT --National Institute of Agronomic Research
22. INRFT --National Institute of Forestry Research
23. OC --Office of Cereals
24. OEP --Office of Livestock & Pastures
25. OMVVM --Office for Utilization of the Medjerda Valley
26. OTD --State Farms Office
27. PPI --Public Irrigated Perimeters Dept. of OMVVM
28. SCM --Mutual Guarantee Society
29. SONAM --National Society of Mechanized Farming
30. SONEDE --Municipal Water Supply Agency
31. STEG --Tunisian Electricity & Gas Company
32. USAID --United States Agency for International Development

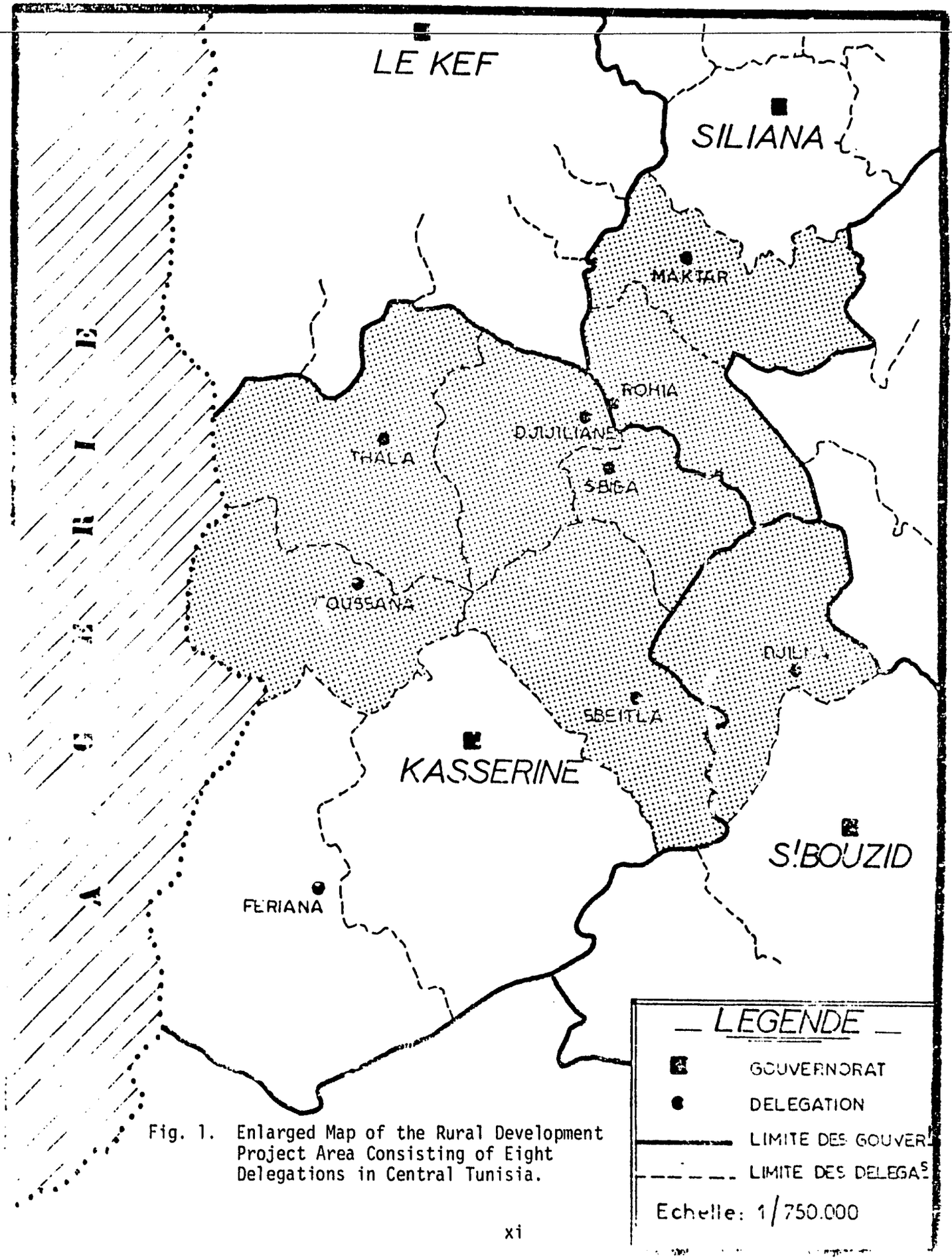

Fig. 1. Enlarged Map of the Rural Development Project Area Consisting of Eight Delegations in Central Tunisia.

SUMMARY AND RECOMMENDATIONS

The work of the team of four consultants for this assignment was arranged through a contract (contract No. AID/afr-C-1139, work order No. 6) between USAID Washington and the Tunisia AID mission, and the University of Missouri, Columbia. The UMC team included one agricultural economist and team leader, one crop scientist specializing in dryland cereal production, and two agricultural engineers--one of whom assumed primary responsibility for the irrigation interventions and the other for the erosion control and rainwater management section of the assignment.

The assignment responsible for this report resulted from an earlier UMC assignment and report prepared under work order No. 5 of the same USAID contract. Among the recommendations in the earlier report were those relating to shallow- and deep-well irrigation, to dryland cereal production (primarily barley), to erosion control and rainwater management, and to procedures for establishing pilot study/demonstration areas in the project area as a basis for longrun developments. The primary responsibility for this assignment was to develop more detailed information and guidelines for implementing each of the four interventions, as well as calendarized budget estimates of the AID financing needed for each.

Goals for all the interventions had a common purpose--to help the small, low-income farmers in the project area achieve greater productivity from their available resources and higher income and better living conditions for their families.

First priority for rapid implementation were the interventions associated with shallow- and deep-well irrigation. This order was suggested because the Tunisian expertise and equipment are already available to permit rapid implementation and because the productivity and earnings of many of the dryland farmers with small farm units could be improved more rapidly, and with greater secondary benefits to still larger numbers of small farmers in the area.

Another high priority intervention, and just as important timewise, is the rapid investment in facilities and personnel training for an aggressive program of applied research throughout the project area, with primary attention to the improvement of cereal production (especially barley) on the dryland farms which predominate the area. Early efforts would concentrate in field trials in the various delegations to determine the best combination of technologies (varieties, fertilizer applications, chemical treatments, tillage and seeding methods, etc.) which can be recommended with confidence to farmers in the area. Experience under similar semi-arid conditions in other countries, indicate the potential for yield increases in the magnitude of 200-400% above the low yields presently realized. With a foundation of successful applied research and well-conducted extension follow-up demonstrations throughout the eight delegations, this intervention has the potential for profound and widespread improvement in the welfare of small farmers in the area.

Of longer time requirement for implementation, but of even greater importance for the longrun improvement of the agriculture

of the area, is the proposal for establishing pilot study/ demonstration areas in selected locations, primarily as settings for applied research and demonstrations of more effective methods of erosion control and rainwater management than now are practiced in the area. Since these new methods of controlling erosion and managing rainwater for more effective use can be implemented successfully only as basic parts of complete farming systems, the pilot areas will require development of complete, longrun plans for each farm unit involved. Experience elsewhere has shown that the cumulative effect of coordinating the application of several proven technologies in complete farming systems can lead to substantial increases in earnings and, at the same time, conserve and improve the land and other resources for future generations.

Establishing the pilot areas and extending the results throughout the eight delegations is a longtime effort and results cannot be realized quickly. However, since the capital requirement is low, it is suggested that one or two pilot areas be initiated early in the project development in order to establish patterns, gather performance data, and train personnel for future expansion.

Attention is directed to earlier sections of the report for more detailed suggestions, and specific recommendations for implementing and financing the proposed interventions. Calendarized budget recommendations are summarized in Appendix Tables A-5, B-2, and C-5 through C-8 for possible USAID financing. The proposed capital investments are substantial. But the wisdom of making them is considered highly questionable unless adequate personnel for

supervision, applied research, on-the-job type extension, and various service activities can be assured by the GOT, along with supporting facilities such as appropriate vehicles for transportation.

To further enhance and accelerate development of agriculture in the project area, the UMC team urges consideration, and financial support, for initiating a few closely related activities not included in the current assignment. These include attention to expansion of apiculture interventions, to improved pasture and forage production, to supplemental enterprises, and to informational travel and study for key administrative and service personnel.

Apiculture seems to offer considerable promise for some low-income farm families to enhance annual earnings through the sale of honey. Those families living within Forest Service areas or nearby may be in best location for this supplemental enterprise since rosemary and various flowering shrubs and plants seem to provide an abundance of nectar most years. Since several families already have experience in caring for bees in Rohia, Maktar, and perhaps other delegations in the area, a basis for expansion already exists. It is suggested that some modest AID financing be considered for providing equipment and training in apiculture and in honey extraction and marketing as well.

Pasture and forage production constitutes a major land use in the project area and is essential for supporting the large numbers of sheep, goats, cattle, and work animals. However, rangelands are severely overgrazed and low in productivity. While not a part of this assignment, it is recommended that two essential steps

be initiated during the current project period to aid in longrun improvement of rangeland in the area.

The first is adaptive research to identify species of grasses and legumes best adapted to the soil and climatic conditions which prevail in the area. Possible sites for such applied research are at Ouesseltia and the Denglos perimeter where some facilities already exist for some of the controls needed for such studies.

The second step would involve conceptualizing and experimenting with some alternative strategies and procedures for controlled grazing on rangelands. Without such, new seedings of improved perennial grasses and legumes are doomed to failure from the start. Since social and cultural traditions are involved, this is a difficult task. However, since many families in the area rely heavily upon sheep and other forage-consuming livestock enterprises, solution to the problem must be a part of any successful, longrun development project.

Observations in the project area, coupled with some preliminary budgeting, indicate that most of the low-income farm families in the area with small land holdings must rely upon greater diversification of enterprises in order to make much improvement in family income. This necessitates greater attention to labor-intensive and cash-generating supplemental enterprises. Such things as apiculture, the production of almonds, pistachios, spineless cactus and, perhaps, millets and sorghums in the dryland area might be considered. Expansion of family-centered handicraft enterprises--using local materials such as alfa grass--also may provide opportunities for fuller employment and higher income.

Finally, the longrun success of the rural development project in Central Tunisia will hinge largely upon the knowledge, vision, and dedicated leadership of the administrators, scientists, and technicians who direct the many activities. In view of this, it is recommended that some of the AID participant training funds be set aside for short-term USA assignments for key personnel to visit selected areas to study and observe successful innovations, technologies, and methodologies which might be adapted to the project area.

I. INTRODUCTION

1.1 This report is the result of a contractual arrangement between the University of Missouri, Columbia (UMC) and USAID, Washington and the AID Mission in Tunisia. The work was performed under Contract AID/afr-C-1139, Work Order 6. A copy of the contract and work order is included in Appendix Section F.

1.2 A team of four consultants, who collaborated in making the evaluations and recommendations included in this report, consisted of the following members:

Albert R. Hagan, Agricultural Economist and Team Leader
Itil Asmon, Agricultural Engineer
Floyd E. Bolton, Agronomist, Crop Science
Charles F. Cromwell, Jr., Agricultural Engineer

1.3 Two of the team members, Hagan and Cromwell, are regular members of the University of Missouri staff in Agricultural Economics and Agricultural Engineering, respectively. Dr. Asmon works as a private consultant and Dr. Bolton is regularly on the staff at Oregon State University where he specializes in cereal production under dryland conditions.

1.4 In order to expedite the work, different parts of the assignment were allocated to individual team members for assembling and analyzing data and writing related sections of the report. Dr. Asmon assumed primary responsibility for the irrigation section; Mr. Cromwell for the section on erosion control and rainwater management; Dr. Bolton

for the section on barley production and dryland farming; and Dr. Hagan for the section on establishing pilot study/demonstration areas, for economic evaluations, and for general organization and preparation of the final report.

1.5 Work on this assignment was completed during June, July, and early August of 1978. The agricultural situation in Central Tunisia, the goals for development, and the specific objectives of the current assignment will be reviewed briefly.

Agricultural Conditions in the Central Tunisia Rural Development Project Area

1.6 During the period from late February through April of 1978, a consulting team from the University of Missouri made an overall assessment of the agricultural potential of the Central Tunisia project area and a report summarizing these evaluations and recommendations was published in April, 1978.[1] The assignment was completed under Work Order No. 5 of the above USAID Contract.

1.7 Descriptive data for the project area were included in the above report in some detail and will not be repeated here. However, a few conditions which bear directly on the current assignment will be reviewed briefly, especially those related to land and water resources, present land use, and constraints which hamper development and improvement of the agricultural sector.

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[1] Cromwell, Charles F. Jr., Albert R. Hagan, Early M. Kroth, and Michael F. Nolan, An Assessment of the Agricultural Potential of Central Tunisia - Evaluations and Recommendations, April, 1978.

1.8 Land resources are quite varied throughout the eight delegations of the project area. In fact, heterogeneity of soil types and conditions is the predominant characteristic of the area. Topography ranges from broad valleys to steep, rugged terrain, much of which is in public forest land. Wide plains, consisting of level to gently rolling land with long slopes, also characterize much of the cropland in several delegations, such as in Thala and Foussana.

1.9 Water is the most limiting resource in the area. Rainfall is sparse and erratic, ranging from an annual average of 268 mm in the Djilma delegation to 400 mm in Thala. It is seasonal in nature with most falling during the winter period and very little during the summer months, June through mid-September. Rains often are intense and sometimes accompanied by hail and strong winds. Groundwater is adequate for limited shallow-well irrigation in some areas; for deep-well irrigation in others. In some places, such groundwater is almost non-existent and water for human and livestock use must be transported for long distances.

1.10 Land use in the area ranges from intensive vegetable and fruit production on farms which have access to irrigation water -- either from shallow wells or within irrigation perimeters -- to forest and rangeland in areas unsuited for crop production. Between these two extremes cereal production (barley and wheat) is the predominant land use. But yields are low, averaging little more than 2 Qx. per ha in many parts of the area, and methods of production are primitive with no organized rotational patterns (Dr. Bolton later describes this as "opportunity cropping"). Likewise, the so-called pasture and rangelands are

depleted and severely overgrazed. Substantial acreages of spineless cactus have been planted in recent years in connection with "food-for-work" programs in order to provide survival-type forage for livestock (predominantly sheep) during extreme droughts. Further details about current land use are included in Chapter IV.

1.11 Constraints to making substantial agricultural improvements in the Central Tunisia project area are numerous and formidable. This is especially true for those affecting the farm families who are restricted to the small-farm holdings which predominate the area. Some constraints which demand attention in implementing the proposals and recommendations in this report are itemized below:

1. Shortage of water and failure to make most effective use of the water available -- both groundwater and rainwater;

2. Eroded and depleted soils upon which future increases in agricultural productivity must depend;

3. Extreme population pressure on the water and land resources available -- associated with unemployment and underemployment of human labor and general lack of opportunity for rewarding off-farm work and family income;

4. Small, fragmented farm holdings, with inadequate land titles, in most cases, to provide security for conventional loans;

5. Traditional farming methods and cultural practices resulting in low yields and productivity from resources used;

6. Resultant low income of small-farm families, leaving little, or no, margin for capital accumulation and risk assumption;

7. Inadequate access to production inputs on a timely basis;

8. Lack of convenient access to product markets and an associated shortage of processing and storage facilities for handling surpluses of perishable crops such as fresh vegetables and fruits;

9. GOT pricing policies which seem to favor price stability for urban consumers over output -- increasing incentives for producers;

10. Inconvenient access to potable water for human and livestock use, requiring inordinate commitment of human labor and transport facilities to water-hauling activities;

11. An almost total lack of applied research in the project area to guide recommendations for new technologies and improved farming systems which are mandatory for any measureable increases in productivity; and

12. Inadequate extension personnel and type of services to bridge the gap between known and emerging technological information and the operators of the small farms in the area.

1.12 These constraints, and others, are discussed more explicitly in other sections of this report. While they may seem insurmountable, members of the Missouri agricultural assessment teams feel that notable progress can be made in overcoming many of these over time, through realistic interventions and prompt, concerted action in implementing them on a sound basis. Suggestions for doing so is the central theme of this report.

Goals for Agricultural Development

1.13 Goals for improvement of agricultural productivity in the project area and the income and well-being of the small-farm operators and their families were presented in some detail in the earlier UMC report. Primary goals which guided the proposals in the current effort are as follows:

1. to help operators of small farms in the project area make fuller and more effective use of their limited resources and achieve higher incomes and better living;

2. to explore the probable impact of applying new agricultural technologies, and combinations of them, in achieving the above goal;

3. to conceptualize, evaluate, and demonstrate new longrun systems of farming which will help small farmers restore and improve the soil, grazing lands, and other resources

and, at the same time, generate higher and more stable earnings from their farming units;

4. to suggest kinds of applied research, conducted on farms in the project area, which will provide a sound basis for specific recommendations and for longrun development; and

5. to propose the kinds of extension personnel and programs which are considered essential for implementing the interventions recommended.

Specific Objectives of the Current Assignment

1.14 Specific objectives for the current assignment are itemized in Work Order No. 6 as follows:

1. To complete a descriptive plan for the specific interventions selected from those proposed in the UMC report; and

2. To furnish on-the-spot expertise and reports, to USAID/GOT, to accomplish incorporating the technical interventions into the design of the project. Selected interventions to increase production and raise farm family incomes:

   a. Pilot, method/result, demonstrations (1) deep and shallow water well development for small-scale irrigation; and (2) rainwater management and erosion contol using terracing, collection, and spreading techniques; and

   b. Assess and develop technical assistance requirements and plans aimed at increasing barley production in the project area.

1.15 For a more realistic approach in implementing these interventions, a three-way classification was conceived, based upon the time interval required for implementation and for results to materialize.

1.16 The first category consists largely of irrigation interventions, especially those relating to improvements in existing shallow wells and the construction of new ones. Such efforts can yield quick returns in the form of higher productivity and earnings for hundreds of small farmers in the area directly, and much greater numbers indirectly through generation of additional employment opportunities.

1.17 From the intermediate point of view, time-wise, are the recommendations for greatly improving the production of cereals (wheat and barley) in the project area. Some delay is involved until applied field studies throughout the project area reveal those technologies which can be recommended and widely demonstrated with some degree of confidence. Since a high percent of the small, dryland farm units now produce these cereals, this intervention has potential for greatly enhancing the productivity and earnings of large numbers of small farmers in the area.

1.18 In the longrun category are the interventions for erosion control and rainwater management and for establishing pilot/study/demonstration areas in selected locations. The erosion control and water management practices must be coordinated with other improved technologies in complete farming systems before any appreciable longrun benefits can be realized. The purpose of these efforts is to evaluate and demonstrate the cumulative effect of adopting whole new systems of farming which will establish a pattern and foundation for longrun improvement and stability of farming in the area.

1.19 Since such pilot areas require a period of several years for development and since limited capital investments are required, it is recommended that they be initiated early in the Central Tunisia project.

II. PROPOSALS AND SPECIFICATIONS FOR SHALLOW AND DEEP WELL DEVELOPMENT FOR SMALL-SCALE IRRIGATION

Background Information

Available Data on Phreatic Aquifers in the Project Area

2.1 Appendix Table A-1 shows the total groundwater resources, present utilization and remaining potential in the project area. The aquifers in the project area have been adequately studied (see references in Table A-1), to the extent that sufficient data exists for implementing a groundwater utilization program; and only the execution of such a program can provide additional data regarding the sustained aquifer yield.[1] Since the thrust of the present project turns out to be groundwater utilization by means of shallow wells (which dry out if the groundwater table falls by more than about 3m), it is prudent to utilize only the minimum proven aquifer yield until experience with the new wells indicates the possible sustained yield of the aquifer.

2.2 Table A-1 shows that the minimum proven yield is about 444 l/s. Subtracting the groundwater potential of Djilma (almost all of which is earmarked to satisfy the domestic and industrial water needs of Sfax), the groundwater potential available for agricultural development is only about 250 l/s of continuous flow. However, since in the project

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[1] Only in Thala delegation are additional studies necessary before exploitation can start in some areas.

area shallow-well irrigation is probably the most effective means to improve small holder income, this modest potential should be fully utilized.

2.3 Appendix Table A-1 also shows that, excluding Djilma, the main potential for additional groundwater utilization lies in Foussana and Thala.

2.4 The Table A-1 refers only to the main valley aquifers. The total groundwater potential is higher due to the existence of small aquifers and underground flows of water courses (oueds), which can be captured by shallow wells.

Current Situation of Shallow and Deep Wells in the Project Area

2.5 Existing shallow wells. The number of shallow wells in the project area is constantly increasing as ever more farmers dig wells, and the GOT services do not have an up-to-date count. However, Appendix Table A-2 shows that about 1080 shallow wells exist in Thala, Foussana, Rohia, Djilma and Djedliene delegations, and that about 90% of these wells are concentrated in Thala, Foussana and Rohia delegations. On the other hand, Maktar, Sbiba and Sbeitla delegations have a total of less than about 50 shallow wells and the potential for increasing this number is insignificant; consequently, these 3 delegations have not been included in the shallow-well development program.

2.6 Shallow wells typically have a depth to the water table ranging from about 3 m in Djedliene and 4-6 m in the Rohia to about 5-10 m in Foussana. Their depth below the water table is up to 3 additional meters. Their diameter is usually 3-4 m (the larger

diameter is preferable as it creates a larger underground reservoir which permits a longer pumping period and thus a higher well yield).

2.7 Such a shallow well usually has a discharge equivalent to 1-1.4 l/s flowing continually. It is typically pumped at a rate of 5-8 l/s in the morning for 2-3 hours until it is emptied and for a similar period in the afternoon. A motor-equipped well usually irrigates 2-3 ha of winter crops (supplemental irrigation), and 1 ha of summer crops. All wells observed were irrigating vegetables (tomatoes, peppers, pumpkins, etc.), usually with interplanted rows of young trees. Every shallow well is usually owned by one farm family, and each farm family usually possesses only one well.

2.8 The quality of shallow-well water is generally satisfactory as the salt content is usually 1-2 g/l and rarely exceeds 3 g/l.

2.9 Condition of shallow wells. Shallow wells are found in all stages of development, namely:

1. a mere hole in the ground reaching just below the water table;
2. a well deepened to 3 m below the water table and lined some distance above it; or
3. a well lined up to the ground surface and sometimes equipped with a small (9 m3) above-surface reservoir.

2.10 Shallow wells may be equipped with an electric motor, with a diesel appliance motor (typically 3 to 9 HP), or only with an animal-drawn appliance (dilu) or a hand bucket. Most diesel motors are of national manufacture (HATZ or FARYMAN), equipped with pumps made in Tunisia (MENZEL-BOURGUIBA). Some use European-made pumps (e.g., KSB or ALTA) and motors (e.g., STEYR). None utilize U.S.-made motors and

pumps. The cost of diesel fuel is TD 0.060/liter and that of electricity (daytime rate) is TD 0.016/KWH.

2.11 Of the motors and pumps observed during the field trip, the large majority (probably over 90%) were in operating condition. The exception was in Qued Kerib (Djedliene delegation), where out of 24 perfectly-constructed wells only 7 were functioning. Significantly, these wells were constructed by a donor-financed project according to strictly technical criteria, without adequate beneficiary selection and participation in the construction and with no extension follow-up. In other locations, reasons cited for the non-utilization of some pumps were salinity problems (in Rohia) and slowness of the STEG (Societe Tunisiene d'Electricite et de Gaz) in repairing malfunctioning transformers. Diesel motors are probably out of operation also because of poor maintenance, although there exist repair shops in Kasserine and Sidi Bou Zid.

2.12 The quality of the equipment seems satisfactory. However, in most cases the equipment is selected without regard to well depth and capacity, and consequently is often too large or too small for the well in question.

2.13 Farmer interest in shallow wells is high. Many farmers are digging wells in the hope of qualifying for credit to acquire a pumpset; a number of farmers have purchased pumpsets out of their own savings; and credit institutions in Kasserine alone reportedly receive credit applications from over 200 farmers per year.

2.14 Existing deep wells. Records of the DRES (Department de Ressources de Eau et de Sol),[1] data collected by the CNEA (Centre National d'Etudes Agricoles) and field observations by the mission showed the number of deep wells in the region to be approximately:

Delegation	Operating Wells	Closed Wells	Total Wells
Foussana	1	4	5
Thala	-	1	1
Sbiba	6	2[2]	8
Sbeitla	7	4	11
Djilma	12	3	15
Rohia	-	5[3]	5

2.15 Condition of the deep wells. The SONEDE is constructing a large aqueduct from Djilma to Sfax to convey water for domestic and industrial purposes. Owing to the size of the aqueduct and the priority given to those uses, it is probable that the recently constructed and still unutilized wells in Djilma will not be used for agricultural purposes. The mission found in the project area only five unutilized wells which, with additional investments, could be used for irrigation:

1. four wells in Foussana - SF4 and SF5 with 50 l/s each, SF3 and SF6 with 20 l/s each (two of these wells are shown in Figure A-1). These wells have been drilled about 1974 and capped in expectation for the Central

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[1] Annuaire de l'Exploitation des Nappes Profandes de la Tunisie 1977, DRES.

[2] These are probably standby wells which were not necessary in 1977.

[3] Reconnaissance wells - not intended for utilization.

Tunisia Project to assume the costs of perimeter developments; and

2. one well in Thala (Ein Hdia), with about 30 l/s capacity, which is partially equipped (the pumpsets, reservoir and main conduits are in place).

Existing Irrigation Perimeters

2.16 The following public irrigation perimeters, based on dams and/or deep wells, are operating on the project:[4]

Delegation	Irrigable Area, ha Winter	Irrigable Area, ha Summer	Irrigable Area, ha Winter	Irrigable Area, ha Summer
Sbiba	1667	600	1300	600
Sbeitla	160	100	90	75
Djilma	1020	n.a.	480	n.a.
Rohia	1300	n.a.	634	n.a.
Total	4147		2504	

2.17 An FAO evaluation of these irrigated perimeters[5] found the infrastructure to be rather complete but quite underutilized. The underutilization was indicated by factors such as:

1. a small ratio of the irrigated to the irrigable area;
2. a high percentage of dry-farmed or partially irrigated cereals in the perimeters;
3. underirrigation of vegetables and forage crops; and
4. underirrigation or abandonment of plantations.

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[4]Source: CRDA-Kasserine (as quoted in Donnees Agro-Economiques de Base sur la Tunisie Centrale, CNEA, 1978.

[5]O. Radelet and P. Martini, Developpment Agricole des Perimetres Irrigues de la Region de Kasserine en Tunisie Centrale, FAO, Rome, Nov. 1974.

2.18 It was also noted that at that time cultural practices on the public perimeters were poorer than among owners of individual shallow wells. This state of affairs was ascribed to the following causes:

1. settlement of the perimeters by former nomads who had no tradition of irrigation;
2. lack of land titles; and
3. lack of marketing at remunerative prices.

2.19 Since the publication of that report, however, the performance of the public perimeters has been steadily improving. The following table[6] compares the utilization of the Sbiba perimeter in 1972 and in 1976:

	1972		1976	
Surfaces Planted, ha	Summer	Winter	Summer	Winter
Vegetables	335	196	370	280
Forage Crops	119	209	150	540
Cereals	--	775	--	350
Total	454	1180	520	1170

2.20 The table shows that the area of summer crops has increased by 15%, indicating better water use, and that the area used in the winter for vegetables and forage crops has increased by 100% at the expense of the lower-cereals.

2.21 However, due to the low water charges (TD 0.004/m3, as compared to operation and maintenance costs of about TD 0.017/m3), the perimeters are not self-financing. In 1977 the administration of the Sbiba perimeter has reportedly had an income of about TD 22,000, as

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[6] M. Ech-Chebeane and M. Bouratbine, Donnees Agro-Economiques de Base sur la Tunisie Centrale, CNEA, April, 1978.

compared to expenses of TD 93,000, which amounts to a subsidy of about TD 120 annually for each of the 600 beneficiaries.

Salinity and Drainage Problems

2.22 Salinity and drainage problems do not seem a significant constraint to development of a well irrigation program, thanks to the good water quality and adequate slopes of the well sites. Only in the Rohia plain were some wells out of use reportedly because of salinity problems caused by a high water table. Closer inspection revealed, however, that the problem is mostly or entirely man-made, caused by a concrete watercourse passage placed at an inappropriate level. This watercourse has acted as a dam, lifting the groundwater level in the vicinity.

2.23 Genie Rurale is presently conducting drainage works in the Rohia plain (excavation of main drains by earth-moving equipment), and similar works are planned for draining about 700 ha in Foussana. USAID participation in this project is not recommended for the following reasons:

1. the low benefits (improvement of presently unproductive land, through about 6 years of rain-leaching, to become average-quality dry-farmed land, of which there is no lack in the region) do not justify the cost of about TD 500/ha; and

2. the benefits of drainage (unlike those of irrigation) are long-term and non-localized, so that the construction of drains is not likely to provoke land redistribution in the area, and consequently the benefits will accrue to the few present owners.

Land Distribution Problems

2.24 In the public perimeters the land is redistributed, e.g., in Sbiba the land is parcelled into plots of 2.5 ha (orchards) or 4.5 ha

(vegetables and forage crops). The land redistribution encountered no particular problems in previously dry-farmed areas (e.g., the Cheraya perimeter), but was a long-drawn-out process where previous irrigation rights had to be modified (e.g., the Sbiba perimeter).

2.25 Construction of new shallow wells involves no land redistribution problems since farmers who propose to construct a well possess the 2-3 ha to be irrigated. The problem with shallow wells is that of judiciously defining the criteria for the choice of beneficiaries so that the new wells will indeed be owned by small farmers.

Improvement of Existing Shallow Wells

Number of Wells to be Improved

2.26 Appendix Table A-2 shows that the potential exists for improving about 293 wells in the project area, located as follows:

1. about 200 wells in Foussana (of which approximately 60 are in the Brika sector, 30 in the Mzira's sector and 40 in the Herich sector - Appendix Figure A-1);
2. 23 wells in Djedliene (of which about 9 in the Hmeima sector and 14 in the Terbah sector - Appendix Figure A-2); and
3. about 70 wells in Rohia.

Types of Improvements Needed

2.27 Well improvement consists of (1) deepening the well to about 3 m below the groundwater table, and (2) lining it up to ground level. The cost of these works is about 1500 TD for an average well (about 10 m total depth). One may require beneficiary labor contribution in these activities, to reduce by about 50 TD their cost to the project.

2.28 Three methods are used for deepening the wells:

1. the traditional method, in which the well is excavated to groundwater level, lined up to ground level, and then pumped, excavated and lined below groundwater level;

2. a method in which the lining consists of prefabricated concrete rings, the lowest one equipped with a cutting edge. As the well is excavated, the whole lining slips down, and new rings are added on top; and

3. the newest method, in which the well is excavated and lined down to the groundwater table, and then a suction pipe is driven to a depth of about 10 m further by pumping water down it (jetting). This method is the cheapest and provides the best results, and its use is expanding.

2.29 Table A-2 shows that about 145 existing shallow wells can be provided with electric motors as follows:

1. 100 wells in Foussana (of which about 50 in the Brika sector and 20 in the Mzira's sector are located near a newly constructed high-tension line; electrification of about 30 wells in the Herich sector will require a 4 km extension of the main line - Figure A-1);

2. 36 wells in Rohia, on the existing line; and

3. 9 wells on a new line from Rohia to the Hmeima sector of Djedliene - Figure A-2.

The costs of electrifying a well are:

1.	electric pumpset	300 TD
2.	connection and instrument panel	200 TD
3.	transformer (2000 TD each, one per 20 wells) - per well	100 TD
4.	low tension line, ave. 300 m, at 2 D/m	600 TD
5.	several lengths of portable outlet pipe (e.g., Bauer), to diminish canal seepage	50 TD
	Total	1250 TD

2.30 The advantages of well electrification are higher water yield, lower operation and maintenance costs and higher reliability.

In practice, replacing a diesel pumpset by an electric one increases well yield by 30% to 50%. Wherever wells are located near an existing grid, their electrification is recommended.

2.31 Table A-2 also shows that some 54 presently non-motorized wells may be equipped with diesel pumpsets. Of these, about 40 are in Foussana and 14 in the Terbah sector of Djedliene. A diesel pumpset (including several length of portable outlet pipe) costs about 800 TD. The diesel and pump motor will be of Tunisian manufacture. An engineer of the Central Tunisia Project will specify the motor power and pump capacity required for each particular well. In installing new pumpsets, it is important not only to observe the distance of about 200 m between wells to avoid depression-cone effects, but also to limit the number of pumps in each sector so as to avoid a localized drawdown of the aquifer.

2.32 Replacing an animal-driven water-lifting device (dilu) by a diesel pump is estimated to increase the area per well irrigated during the summer season from about 0.25 ha to 1.0 ha, and during the winter season (supplemental irrigation) from about 0.5 ha to 2 ha.

2.33 Finally, Table A-2 shows that some 200 wells need small improvements to complete their infrastructure. Of these wells, about 20 are in Foussana, 150 in Thala and 30 in Djilma. The improvements in question usually consist of extending the concrete lining up to the ground surface and providing portable outlet pipes to replace the outlet canal and avoid its seepage losses. The cost of such small improvements is estimated at 400 TD per well.

2.34 To recapitulate, the project proposes the following shallow-well improvements:

1. lining and deepening of 293 wells;
2. small improvements in 200 wells;
3. installation of 145 electrical pumpsets; and
4. installation of 54 diesel pumpsets.

Land Preparation Required

2.35 The shallow wells in the project area are typically found on colluvial soils on piedmont slopes, which present an even gradient throughout the small (2-3 ha) area commanded by each well. Furthermore, the traditional method of irrigation consists of filling borders of about 2x2 m each with water; this method minimizes the effect of the microrelief. One may also advance the argument that seepage losses are less of a disadvantage in shallow-well systems than in deep-well or gravity irrigation systems, since the water percolates in a few days down to the water table and may be recuperated by the same farmer or his neighbor, incurring only the variable costs of pumping it. For all of these reasons, land levelling with machinery on the shallow-well perimeters is not considered necessary.

Schedule of Investments in Shallow-Well Improvements

2.36 Appendix Tables A-2 and A-5 show the required investments in shallow-well improvements to be:

1979	1980	1981	Project Total
TD 222,450	TD 304,800	TD 272,750	TD 800,000

Benefits of Shallow-Well Improvements

2.37 The shallow-well improvements are expected to provide an additional discharge equivalent to about 100 l/s of continuous flow, bringing into service about 100 additional hectares during the summer season and over 200 ha during the winter. In addition, the improvements will increase the reliability of services and reduce seepage losses on about 500 ha (summer crops) and 100 ha (winter crops). This will be of direct benefit to nearly 600 smallholder families.

Installation of New Shallow Wells

Number of Wells to be Constructed

2.38 Appendix Table A-3 shows that there exists a potential for constructing about 225 new shallow wells in the project area, located as follows:

1. about 50 wells in Foussana, equipped with diesel pumps (to be located at suitable distances from the existing concentrations at Brika, Mzira'a and Herich to avoid local aquifer drawdowns - Appendix Figure A-1);
2. 45 wells in the Chaker - Sidi S'hil sector of Thala,[7] equipped with electrical pumps;
3. 70 wells in Djedliene (of which 10 in an extension of the Oued Kerib sector and 30 in the Hmeima sector, equipped with electrical pumps, and 30 at Terbah, equipped with diesel pumps - Appendix Figure A-2);
4. 40 wells in Rohia; and
5. 20 wells in Djilma (in the Zarzouga, Thlijane, Selta, Batn-Gazel and possibly the Essed and Guedir Zitoun sectors).

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[7] H. Zebidi, Etude de la Plaine de Kalaa-Djerda, DRES. There probably exists additional potential in other sectors of Thala, e.g., Ein Defla, but its realization requires additional groundwater studies, which should be undertaken during the project period.

These wells will intercept underground flow of local watercourses (oueds) and thus will not be significantly affected by the diversions from the Djilma aquifer to Sfax.

2.39 The number of new wells proposed has been calculated so as to fully utilize the proven minimum yields of the aquifers in the delegations concerned. The total discharge from the improved wells (Table A-3) and the additional discharge from the improved wells (Table A-2) in some cases exceed the available aquifer yield shown in Table A-1. This is because Table A-1 refers only to the potential of the main aquifers in the large valleys, while many of the new wells proposed above will be located in small independent aquifers.

Components of New Shallow Wells

2.40 Installation of a typical shallow well (about 10 m total depth) requires the following:

1. excavation to the water table - 5 workers for 30 days at TD 2/day each (this cost and time may be reduced by the use of a motorized hoist which may be rented for TD 10/day). . . . . TD 300

2. deepening below the water table using a pump (or jetting), and lining up to ground level (Par. 2.28) . . . . . TD 1500

3. diesel pumpset with portable outlet pipe. . . . . TD 800

   OR

   electric pumpset with portable outlet pipe, connections, line and transformer (Par. 2.29) . . . . TD 1250

2.41 The excavation may be undertaken by the beneficiary without specialized equipment and would represent his contribution to the investment. The deepening and lining require specialized equipment and considerable material costs; consequently, these should be furnished by project funds and performed by the project administration or (preferably)

by a small contractor. One may require labor contribution by the beneficiary during this stage as well, to decrease by about TD 50 the cost to the project.

2.42 Consequently, the cost per new well is:

	Diesel-equipped Well	Electrical-equipped Well
Cost to Beneficiary	TD 300	TD 300
Cost to Project	TD 2300	TD 2750
Total Investment	TD 2600	TD 3050

Land Preparation Required

2.43 For the reasons detailed in Par. 2.35, project investments in land preparation (except for the replacement of the main earth canal by a portable outlet pipe) are not deemed necessary for new shallow wells.

Estimated Investments in New Shallow Wells

2.44 Table A-3 in the Appendix shows that excavation of 225 new wells would cost the beneficiaries the equivalent of TD 67,500, while the deepening and lining of these wells and the installation of pumpsets would cost the project administration TD 605,750. This figure includes the cost of 4 km of 3000-volt line from Rohia to Hmeima.

Investment Schedule

2.45 Appendix Table A-5 shows that the investment in new shallow wells may be scheduled as follows:

1979	1980	1981	Project Total
TD 126,250	TD 190,500	TD 289,000	TD 605,750

Benefits of New Shallow Wells

2.46 The new shallow wells will provide the equivalent of about 225 l/s of continuous flow, enabling the irrigation of about 225 ha during the summer and 450 ha during the winter, to the benefit of 225 smallholder families which at present have no access to irrigation water.

Development of Natural Springs

2.47 Natural springs in the project area represent a small but low-cost water resource. A spring typically furnishes 1-1.4 l/s and can irrigate 2-3 ha if effectively utilized. It is used by two or more families. Spring development consists of:

1. construction of a concrete tank to conserve overnight flow and provide a sufficiently strong irrigation stream . . . . . TD 700
2. provision of portable outlet pipes to reduce seepage losses . . . . . TD 50

Total Investment per Spring . . . . . TD 750

2.48 The number of springs available and the cost of their development is as follows:[8]

Delegation	No. of Springs	Investment, TD
Foussana	27	20,250
Thala	5	3,750
Djedliene	2	1,500
Sbiba	45	33,750
Sbeitla	18	13,500
Djilma	2	1,500
Total	99	74,250

[8] Projet de Developpement Rural Integre de la Tunisie Centrale, OMVVM-PPI, Feb. 1978.

2.49 The area irrigated by a spring is comparable to that irrigated by a shallow well, while the investment involved is much smaller (TD 750 vs. TD 2600) and the operating costs are nil. Thus the economic benefit to spring development is obvious.

Development of New Irrigation Perimeters Based on Existing Deep Wells

2.50 As mentioned in Par. 2.15, the opportunity for exploiting unutilized deep wells is limited to four deep wells in Foussana and one in Thala delegation.

The Four Deep Wells in Foussana

2.51 These wells (Appendix Figure A-1) have been capped in 1974 in expectation of Central Tunisia Project funds for their development. The depths of these wells range from 200 to 500 m. Their characteristics are as follows:

Designation	Discharge, l/s	Irrigable Area, ha	Infrastructure Cost, at TD 1900/ha
SF 4	50	120	TD 229,000
SF 5	50		
SF 6	20	30	TD 57,000
SF 3	20	60	TD 114,000
Total	140	210	TD 400,000

2.52 The SF 3 perimeter will be planted entirely with fruit trees, which explains its large area in relation with the available discharge. The SF 4 - SF 5 command areas (which form one perimeter) and the SF 6

perimeter are planned for forage crops and vegetables. The cost of TD 400,000 includes investments in pumpsets, reservoirs, canals, interior roads and levelling. Investments in tree plantations, stables, livestock, etc., will occur after the three-year project period.

2.53 Since these perimeters are at present dry-farmed (barley) and contain no fences or residences, the land distribution process is expected to be straightforward.

2.54 According to the Plan Directeur de l'Utilization des Eaux du Centre de la Tunisie (Ministry of Agriculture, FEb. 1977), these wells pump from an aquifer of $6x10^6$ m^3/year capacity (190 l/s continuous flow), so that they will not exhaust the aquifer capacity. According to recent studies,[9] there is no intercommunication in this region between the shallow and deep aquifers, so that exploitation of the four deep wells is not expected to lower the groundwater table in the Foussana shallow-well development areas (Figure A-1).

2.55 The feasibility studies of these perimeters are being completed by Genie Rurale.

The Ein Hdi- Deep-Well Perimeter in Thala

2.56 In this perimeter the deep well (30 l/s) was drilled about 1970 and the reservoir and main conduits have been completed by Genie Rurale. The PPI (the Irrigated Public Perimeters Department of the OMVVM - Office the Mise en Valeur du Vallee de la Medjerda), which is the organization responsible for utilization of the irrigated perimeters, has not yet accepted charge of this project, ostensibly because

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[9] H. Rahwi, Etude Hydrogeologique de la Cuvette du Foussana, Diplome de Doctorat du 3eme Cyc . Montpellier, Nov. 1977.

some infrastructure elements (secondary canals, land levelling and interior roads) are still lacking. The necessary investment is estimated very roughly to be on the order of TD 100,000. Land tenure problems, however, may be a factor in the slow progress of this project, as the perimeter includes cultivated and inhabited areas. This problem should be carefully assessed before financing of this perimeter is undertaken.

Improvement of Functioning Irrigation Perimeters

Improvement of the Sbiba Perimeter

2.57 The Central Tunisia Project has submitted for the 1979 budget a list of the following improvements to be made in the infrastructure of the Sbiba perimeter:

interior roads	TD 60,000
electrification of pumping stations	TD 30,000
replacement of a standby pumpset	TD 8,000
construction of a protection dike	
--earthworks	TD 250,000
--civil engineering works	TD 85,000
levelling	TD 200,000
studies and inspection	TD 30,000
Total	TD 663,000

2.58 This amounts to an investment of TD 400/ha for the gross irrigated area of 1667 ha.

2.49 With the above actions which are probably necessary (although the economics of the flood protection dike should be carefully reviewed), the perimeter infrastructure will be essentially complete. Further

development should be oriented to intensification of the cultivation pattern.

Improvement of Public Perimeters in Djilma

2.60 For the public irrigation perimeters Djilma, the Central Tunisian Project proposed for 1979 financing of the following actions:

1. Hadjeb 7: 40 ha - levelling and canal construction . . . . . TD 20,000
2. Hadjeb 8: 280 ha - levelling and canal construction . . . . . TD 66,000
3. Sabbalet (Ouled Asker): 60 ha - levelling and canal construction . . . . . TD 24,000

Total area benefited = 280 ha; investment = TD 110,200

This amounts to TD 290 per hectare benefited.

Investment Priorities, Issues and Conditions Precedent

Investment Priorities

2.61 If the opportunities for investment in agricultural infrastructure in the project area were ranked according to the USAID criteria of providing the lowest-income farmers with maximal income increases at lowest investment per beneficiary, the priorities would probably be as outlined below:

1. Creation and improvement of shallow wells and springs should receive the highest priority for the following reasons:

   a. Project investment is medium - TD 2300 to 2750 per family served or about TD 1150 - 1375 per ha.

   b. The benefits, although their calculation has not been undertaken in this report, are expected to be high since the water is used mostly for vegetables.

   c. The investment may be at least partly recuperated and

d. Administrative inputs are minimal.

The main shortcoming of this option is the limited groundwater supply. Therefore, it should be utilized to the fullest extent as this report proposes.

2. Establishment of non-irrigated fruit plantations. while not a part of this section of the report, is considered a fairly high-priority investment since:

   a. Project investment is low (TD 400-500 per ha), including irrigation during the period of establishment by means of a tank truck.[10]

   b. Returns are satisfactory.

   c. Investment per family can be minimal according to the planted area provided per family and

   d. Land resources and the market permit a large expansion of these crops.

The main disadvantage of this option is the long time (5 years) necessary to perceive benefits; however, the same is true for most public irrigation perimeters.

3. Development of new deep-well perimeters should receive a lower priority since the investment is high (TD 3000 - 4000 per ha equipped or about 2-4 times this amount per family) and non-recuperable. The continuous subsidy of the beneficiaries is considerable (Par. 2.21); and the requirements for administrative manpower are high.

4. Improvement of existing perimeters should probably receive the lowest priority among the alternatives considered since the added benefits are likely to be low, and they accrue to a class of farmers which has already been substantially benefited through public investments.

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[10] For the irrigation of young plantations, it is recommended to use unglazed clay jars (costing TD 0.400 each). These are buried to the neck near the roots of the saplings and filled every 15-30 days with water, which oozes continuously to the roots. This, in effect, creates an appropriate technology drip-irrigation system at an investment of TD 20 per hectare.

2.62 The conclusion from this overview is, if budget constraints do not permit implementation of the full TD 2,210,000 program proposed in this report (Appendix Table A-5), then one should keep the sum of TD 1,480,000 budgeted for well and spring development intact rather than reduce all investment items by the same percentage.

Issues

2.63 The following issues need to be resolved before the proposed investment program can be undertaken:

1. Who will be the beneficiaries? Criteria must be defined as to who can qualify to obtain shallow wells and pumps in order to assure that the beneficiaries will not be larger farmers or absentee owners as is often the case at present.[11] Similarly, criteria must be set for obtaining a plot on deep-well irrigation perimeters.

2. Should the shallow wells be provided as a grant or a loan? A case can be made for providing the well linings (TD 400-TD 1500 each) as a grant, since this is a practically permanent investment in infrastructure (many wells lined by the Romans are still in use in the project area). Providing the well lining on a grant basis would place the shallow-well beneficiaries on a more even footing with the beneficiaries of public perimeters, where the infrastructure investments are much higher (on the order of TD 8000 for a 2-ha farm) and no attempt is made to charge the beneficiaries for them (on the contrary, the operation of public perimeters is heavily subsidized as well). On the other hand, pumpsets should be provided on a five-year credit.

3. Who will provide the credits? The existing credit mechanisms in the area entail long delays in approving applications for medium-term credit and have requirements (such as the presentation of land ownership certificates), which, in effect, exclude most small farmers. In order to implement the shallow-well program at the planned rate, credits for irrigation equipment may have to be provided directly by the Central Tunisia Office.

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[11] R. Fraenkel, The Distribution of Irrigation Equipment in Thala Delegation, April 1978.

4. Who will construct the shallow wells? Utilizing several small contractors rather than constructing the wells by Central Tunisia office personnel is likely to speed up execution and reduce costs. Another alternative is to have Care-Medico well-construction teams with a Peace Corps volunteer foreman as a well contractor. This could provide an integrated input to U.S. involvement in Central Tunisia development and speed up development since similar teams are already repairing and improving shallow wells for potable water supplies in Maktar, Le Kef and other places in Tunisia.

5. Who will be responsible for the existing irrigation perimeters in the project area? The present report concurs with the opinion expressed by management personnel of the newly-created Central Tunisia office that operation of the existing perimeters should remain with OMVVM-PPI, at least during the three-year project period so that the Central Tunisia office management should not be distracted by routine operational problems from its developmental tasks. However, if the Sbiba, Hadjeb 7 and 8 and Sabbalet perimeters stay with OMVVM-PPI, it should be decided whether they would still qualify for project funds for infrastructure improvements (Appendix Table A-5, Section E).

2.64 An aspect which turns out to be a non-issue is that of purchasing U.S.-made pumps and motors for shallow wells since this equipment is manufactured in Tunisia as a shelf item in sufficient quantities to meet project requirements. The four pumpsets for the deep wells at Foussana may be ordered from the U.S. (both PEERLESS and WORTHINGTON have representatives in Tunis) or, if this is not convenient, European makes may be purchased with GOT counterpart funds.

Conditions Precedent

2.65 Extension service to shallow-well irrigation sectors. For assuring full utilization of the shallow wells and pumpsets provided, it is deemed essential that the farmers receive adequate guidance. To this end, the new or reconstructed wells will be located so as to create irrigation sectors of 20 to 60 wells each (according to the groundwater potential, and each sector attended by one middle-level extension

agent (adjoint technique). As a minimum, extension staff assigned full-time to shallow-well sectors should consist of the following:

Office	Ingenieur Adjoint	Adjoint Technique
Foussana	1	4 (Brika, Mzira's, Herich Sectors)
Thala	1	3 (Ein Defla, Chaker Sectors)
Djedliene	-	1 (Oued Kerib, Hmeima Sectors)
Rohia	-	1
Total	2	9

2.66 The ProAG should specify as a condition precedent that these persons be assigned by the Central Tunisia office. They should be provided with adequate means of transport.

2.67 The Extension Department of the Central Tunisia office should also employ a higher-level specialist (preferably an M.S. in extension methodolcgy) who will be free from routine supervision duties and able to concentrate on in-service training of the Central Tunisia office extension personnel (for shallow-well, deep-well and dry-farming areas) and on communication with the research institutions. This position should be coordinated with that of the extension training specialist proposed for the Le Kef College of Agronomy.

Marketing Apsects

2.68 While the present report does not deal with marketing, the following observations are offered on this essential subject:

1. Fruit and vegetable collection centers: Considering the benefits which small producers in the area will derive from high and stable fruit and vegetable prices, the feasibility of setting up viable fruit and vegetable collection centers should be studied (taking into account the competition from private middlemen). This may be an appropriate subject for technical assistance in marketing studies.

2. Apricot drying: Apricots, which have a very short harvest period, create a seasonal glut with consequent low prices to the producers. A system for on-farm drying of apricots and their packaging for export should be installed and promoted by extension workers.

3. Almond shelling: 3 kg of almonds in the shell, which have a total farmgate price of about TD 0.240, are converted into 1 kg of shelled almonds, which has a wholesale price of TD 1.200. This considerable price differential may offer significant benefits to small almond producers if they can be equipped with small motorized almond shellers which may be operated by one or a few families.

III. PROPOSALS AND REQUIREMENTS FOR EROSION CONTROL AND RAINWATER MANAGEMENT

Background Information

Current Situation in Project Area

3.1 The water limitation on dryland crop production is easily understood by studying the annual average rainfall isohyetals (Figure IV-1) and from the table of average seasonal and 90% probability rainfall amounts in the Appendix Table B-1. Bolton elsewhere in this report emphasizes the importance of improved management practices to maximize cereal production in dryland culture. Field visits during March and June, 1978, impressed the UMC team with the rain-shadow effect of area mountains. Precipitation amounts for areas south and east of Djebel Semama, Djebel Mrhila, Djebel Bireno, and other mountains are evidently even lower than reported amounts from meteorological stations. Crop conditions in Selta (Jilma), Semama (Sbeitla), and El Hmaima (Jedliane), as examples, gave evidence of quite low rainfall in the 1977-78 season.

3.2 Water and wind erosion. The report, "Assessment of the Agricultural Potential of Central Tunisia," by Cromwell, Hagan, Kroth and Nolan, a University of Missouri team on USAID contract AID/Afr-c-1139 of April 1978, emphasizes the long-range erosion hazard to the most productive soil types of the region. Gulley, rill, sheet and channel erosion are all easily witnessed by the observer in each of the project delegations. Clogging of small reservoirs, diversion structures and natural

channels is frequently seen as deposition occurs at the locations downslope.

3.3 Wind erosion occurs frequently where the field length in the prevailing wind direction is long. Windbreaks are seen occasionally. These are evergreens (such as the tamarisks, cypress, eucalyptus), fruit, oil or nut trees, bordering irrigated perimeters. Spiny cactus serve as both property-line fences and windbreaks in some areas.

3.4 The erosion situation in parts of Maktar delegation can best be described as geologic in scope, i.e., beyond redemption either by manageable conservation practices or by reasonable interventions.

3.5 Previous erosion-control efforts. Small rock dams (gabions) are used frequently by the Tunisian Forestry Department to reduce the velocity of runoff water in gully channels and to trap sediments in the small level spaces that develop above the gabion. These also serve to increase infiltrations of rainfall and aid phreatic aquifer recharge. They could be integrated into terrace systems as outlet control structures for level storage terraces.

3.6 Quite a few kilometers of hand-constructed terraces have been built over the years since independence. Very few broad-based, machine-constructed terraces are seen. Many of these tibia were built as food-for-work employment schemes. In most cases, the terraces have steep faces and backslopes, and an inadequate cross section of lightly compacted soil. In many cases, ridge height is inadequate. Also in some cases, no supervision was given during construction to maintain proper grades in terrace channels and erosion has been concentrated by the work done.

3.7 In a few cases, very good terrace systems have been constructed. This indicates technical training is available in Tunisia but sufficient manpower has not been assigned to the project area for quality terracing to be a continuing program.

3.8 Most of the cactus plantings follow property division lines or pre-existing paths or trails. With contours as a reference, over 90% of the cactus plantings witnessed were planted in a direction that can only be described as "random."

3.9 Tree plantings are rectangular-grid planted with no reference to contours in about 90% of the cases. Occasionally, tree plantings follow terrace orientation.

3.10 The most often planted dryland tree is the olive. It is usually planted in large "blocks" and is seldom strip-planted as a windbreak where wind erosion is significant. It does not provide sufficient projected cross-section density to be very effective alone as a windbreak.

Constraints to Effective Erosion Control

3.11 Lack of applied research. Very little applied research has been carried out for erosion control in Central Tunisia.

3.12 Many factors contribute to the present state of erosion in Central Tunisia in addition to the climatic and soils factors discussed above. The area has not yet received a research priority appropriate to the scope of the erosion problem. Terrace design parameters are needed. Estimates of peak rates of runoff from small watersheds need to be verified by field data. Effect of terraces on runoff rates need to be known.

3.13 The terracing effort and other erosion-control construction devices will need trained, experienced, and concerned personnel. Short-term training in the Midwest can be quite helpful for supervisors.

3.14 Lack of trained personnel and other factors. There is a lack of trained personnel with available time to plan water management systems and supervise construction. Area farmers have not yet seen the need for erosion control. Small-parcel land holdings inhibit construction of a reasonable-sized terrace system. Overstocking and overgrazing of rangeland appear irrational to first-time visitors to the area. The residents were nomads until the present century so ingrained habits of nomadic herding are a hindrance to systematically farming for erosion control.

3.15 Present tillage methods are most commonly determined by the opportunistic use of government, cooperative, or private tractors with discs that "happen to be working in the area." No weed-control tillage is done. Contour plowing is rare. No effort is made to provide mulch material for the soil surface due to the need for fodder.

Goals for Erosion Control and Rainwater Mangement

3.16 Goals for dryland water management in the project area are simple and specific. These are to maximize agricultural production, which is limited by available water, by making best use of the rainfall for current season productions and to minimize erosion in order to preserve the irreplaceable soil resource in a useable condition for future generations.

New Technologies to be Introduced

Broad-based Storage-type Terraces

3.17 Wischmeier in the late 1950's and early 1960's proposed a simple multiplicative relationship of factors affecting soil loss on cropland. The relationship proposed is as follows:

$$A = R \quad K \quad L \quad S \quad C \quad P, \text{ where}$$

A = soil loss in tons per acre per year
R = rainfall factor
K = soil-erodibility factor
L = slope-length factor
S = slope-gradient factor
C = cropping-management factor
P = erosion-control practice factor

3.18 This is commonly referred to now as the Universal Soil Loss Equation.

3.19 The rainfall factor (R) has been forecast for Central Tunisia by Arnoldus as about 100 in U.S.A. units which is a low value; comparable to Western Kansas, Northern Wisconsin, and the Texas-New Mexico boundary area. The low R-value perhaps explains in this mathematical equation approach to erosion studies why the Central Tunisian area has continued to produce grain for 2500 years. Man-made change in this climatic factor is not within the scope of present generation expectations.

3.20 Another factor not changeable but of more concern is soil erodibility (K). Soil properties that affect erodibility by rain and runoff include infiltration rate, permeability, soil moisture-holding capacity, and structure.

3.21 The slope-length factor (L) is most easily reduced by construction of terraces (tibia) and diversions, or by contour strip-cropping with vegetative strips to catch the detached soil particles. Spineless cactus planted on a slightly elevated bed on a true contour can serve as a catch-strip for contour farming and an important livestock feed in Central Tunisia. The L-factor is reduced from the total field length to the interval of terraces or contour strips.

3.22 The slope-gradient factor (S) probably will not be significantly changed in Central Tunisia except by land levelling in preparation for irrigation around wells. There is a slight increase in 'S' for the terrace interval after terraces are constructed.

3.23 The cropping-management factor (C) presently applicable to Central Tunisia has been described by Bolton elsewhere in this report as "opportunity farming." Changes he proposes to significantly increase yields by dryland management system will serve to decrease the erosion hazard slightly. If stubble can be left in place ungrazed, higher yields of grain can accompany greatly reduced erosion or low C-factor.

3.24 The erosion-control practice factor (P) again illustrates the erosion-control benefit of terracing. The P-factor quoted by Beasley[1] for terraces is 20% of the contour factor and the contour factor is 50% of the value of the usual tillage practice of uniform tillage over large cereal fields in Central Tunisia usually with up-and-down plowing. In other words, the practice of terracing and contour farming parallel

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[1] R. P. Beasley, Erosion and Sediment Pollution Control, Iowa State University Press, Ames, Iowa, 1972.

to the terraces reduces the erosion hazard to 10% of the present rates of erosion.

3.25 Terracing is not a new technique for Tunisia. So many kilometers of tibia have been constructed that many policy-makers are dissatisfied with the practice. The emphasis now needs to shift to "quality control." When broad-based level storage terraces that store 7-10% of annual rainfall are constructed, increased productivity from the stored water will result and erosion will be reduced by 90% over a long time period--if the terraces are maintained. Occasional repair will be required with any terrace system. Rare storm events can be expected to overtop terraces occasionally. After-storm repair is required for maintaining a permanent system of terraces.

3.26 When terraces are planned, complete management of the water falling on and running through the area must be considered. Terrace spacings are normally in the 25- to 45-meter range, depending upon average land slope between terraces. If the top terrace in the field is at greater distance downslope from the crest, then a diversion must be used to prevent excess flow into the topterrace. The other terraces are laid out with a vertical spacing criteria appropriate to expected rainfall intensities, soil type, and average land slope between pairs of terraces. A simple formula often used is:

$$VI = X \quad S + Y$$

where VI = vertical interval between terraces

S = average land slope between terraces

X = a slope multiplier selected after applied research on similar soils

Y = a constant added appropriate to erodibility of the soil and expected plant cover (from 30-100 cm)

The average horizontal interval (HI) from the preceding criteria will be:

$$HI = \frac{VI}{S} \times 100$$

3.27 Local field testing is needed to determine most appropriate outlet structures for level storage terraces. Where rock flumes are hand-constructed, a very narrow weir-type structure might be used at the ends of terraces. The time of inundation of the crop in the terrace channel and the infiltration rate of the soil must be of concern when determining terrace-channel drainage time. Usually 24-hour drain time will not cause crop damage. The volume of storage for the level terrace system should be 25-50 mm of depth over the spacing of the terrace interval.

Diversions and Silting Basins

3.28 Diversions are channels constructed across a slope to divert runoff from land upslope, away from the land being protected downslope. In order to "heal" or cure or eliminate a gully, runoff water must be removed from it. Where terraces are to cross small gullies, a diversion is required above the terrace system to remove water from the gully. A key part of the diversion system must be a silting basin at each gully crossed. Some water will be stored temporarily in a pool during each runoff event. Upstream, large-diameter eroded material will be trapped and retained in the silting basin so that cross-slope diversion channel capacity will not be lost due to siltation. These basins should have the deposited materials removed occasionally to prevent escape into the cross-slope diversion channel.

3.29 One situation frequently encountered in Central Tunisia is where forest land occupies the upper slope and cereal fields occupy

the lower slope. This situation always requires a diversion at the lower limit of the forest land to protect the more productive land below (see Figure III-1).

3.30 Diversion channels must have a minimum water carrying capacity sufficient to accomodate the rainstorm event with a ten-year return period. Capacity is determined by the velocity of flow and the channel cross-section area. Channel velocity is limited to non-erodible velocities, which need to be determined by applied research in the area. In all probability, cereal-capable soils of Central Tunisia will not be able to stand channel velocities greater than one meter per second except where rocky or stony soils are encountered.

3.31 Technicians accustomed to using Manning's formula for calculation of velocity will be using an English-unit of .02 to .025 for bare channels. For stony channels, a value as high as .1 might be used. Tunisian engineers or technicians are trained to understand this technique and limitation for channel flow problems. The technique of integrating a complete water management system for a large area does not appear to be understood, based on field visits to all eight project delegations.

Small Water-Storage Impoundments

3.32 Small water-storage impoundments can be integrated into a diversion plan (Figure III-1). There should be no confusion between a small structure designed for a silting basin and a somewhat larger structure for water supply. If the water storage structure is part of the diversion, it will not fill with silt quickly as it most probably

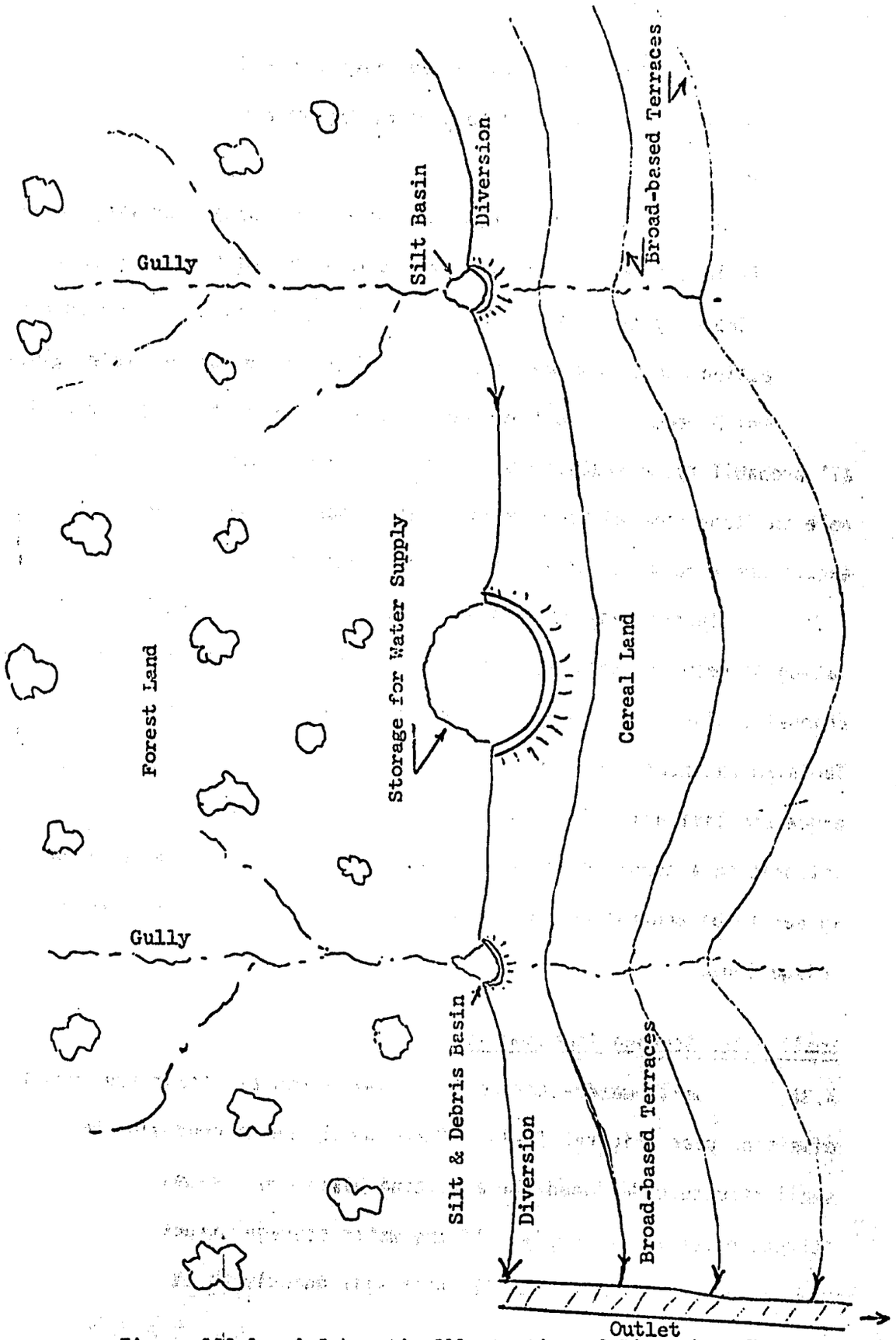

Figure III-1 - A Schematic Illustration of Diversion, Terraces, Silt Basins, and Small Water Storage Basins to Protect Terraced Cropland from Forest Land Upslope Runoff.

will when constructed at a "natural" storage site. Also, the diversion channel will act as the spillway as well as the supply channel. For other types of small water storage structures, the outlet structure required to provide stability and protection for the storage structure may be as expensive as the storage structure.

2.33 These small water-storage structures need to be constructed with good compaction. In Central Tunisia, this means wetting the borrow material and using mechanical compaction such as "sheepfoot" or heavy rubber-tired rollers. A wide gradation in soil particle size from coarse sand to clay is required for a good degree of compaction. Single-particle-size soils do not make good storage materials.

3.34 Storage volumes for small impoundments need to allow for household use and animal use for the population served. Evaporation losses will be high in the area due to high winds and low humidity. Seepage losses may be high on the granular soils. Since people now travel 8-10 km for household water in the drier upslopes of the project area, any system of storage of water for domestic use reduces the number of days per year spent depending on the distant springs or wells and improves the human condition of the lowest income group of the population.

Water Spreading Techniques

3.35 Water spreading from gullies is an old Tunisian practice. The limitations on spread of this practice are more social than technical. Most of the systems established under colonization and under cooperativization have failed under individualized, fragmented ownership. No one is available to operate the system in the midst of the rain or to

repair it between rains. Fraenkel visited a small site on June 1, 1978, where three farmers who were brothers had recently constructed a small water diversion and spreading system that worked well during runoff events in early 1978. Many such opportunities exist in the eight delegations. Each is unique. The technical guidance needed for a system would be easy to provide. The social guidance to agree on labor inputs needed and water division during runoff must be provided parallel to the technical guidance. The value of the extra water added to stored soil water can only be determined by field trials and the data will be difficult to extrapolate due to the uniqueness of each site.

Contour Planting and Tillage Operations

3.36 Tunisia has legislation or decrees "requiring" plowing to be on the contour. It is not enforced and is generally ignored. In fact, much of the plowing is up-and-down slope. Contour plowing and contour planting will reduce erosion 40-50%. Contour planting of spineless cactus at the usual spacing of 4-8 m also serves to reduce erosion greatly.

3.37 If olives and almonds were contour planted, supporting inter-culture for weed control or for temporary cereal culture in new plantings could be done on the contour. It is unfortunate that a rectangular grid pattern of young trees is so pleasing to the human eye and is such a widely-accepted practice in Northern Tunisia. Contour planting of all crops would be an easy conservation measure of long-range benefit at no out-of-pocket cost. Obviously, a dedicated extension effort is needed based upon local field trials and demonstrations.

Coordination of Mechanical Erosion Control
With Other Improved Technologies

3.38 Terraces, diversions, contour planting and other erosion-control devices will not appreciably increase net spendable income to cultivators in the area unless these practices are coordinated into a best-possible total management system for crop production. Pilot demonstration areas should be set up where applied data can be gathered and where extension tours and field days are part of the plan. The concept is further discussed in Chapter V of this report.

Calendar of Events for Implementing Intervention

3.39 The erosion-control intervention should begin with long-term participant training for M.S. degrees in soil conservation and erosion control for two participants under the Technology Transfer program for the first year. During this same year demonstration sites need to be selected. These will be primarily on cereal-capable land of 2-6% slope, probably government owned. Short-term training for experienced technicians should also begin early.

3.40 Planning will begin late in the first year as the first short-term participant trainees return to project offices. After detailed plans are drawn up for the erosion-control work and the management system is planned for the farming units, then a construction schedule must be established.

3.41 The second year will be a busy construction period establishing diversions, terraces, silting or debris basins, outlets, etc. As each unit of construction is completed, the various farm management interventions must follow quickly, beginning with soil testing to

identify special soil fertility problems that might be aggravated by construction.

3.42 By the third year, data collection will be in full swing and procedures to move out from the demonstration units to other private land will be set up by concerned technicians.

3.43 It is expected that Soil Conservation Service technicians of the Department of Foresty will take a leadership roll in designing and constructing the erosion-control measures and that they will work closely with extension and applied research workers who will also be involved with the demonstration units.

Summary and Evaluation of Inputs of This Intervention

General Summary and Purpose of Intervention

3.44 The impacts of the erosion-control intervention proposed will be both short- and long-range. The short-range benefit will be from doubling stored soil moisture under the terrace channel. A short-range detriment will be the disturbed land in the terrace construction zone and the exposed subsoil in the terrace channel area. Soil testing will be required in order to prescribe fertilizer doses to bring the channel area back to peak production. The long-range benefit will be a tenfold decrease in rate of loss of topsoil where terraces are constructed and some increased recharge of downslope phreatic aquifers due to detention of local runoff from rainfall in level terraces.

3.45 The erosion-control intervention will show maximum impact as part of an integrated dryland agriculture system. Present "opportunity farming" practices will need to change. A coordinated field trial-

demonstration program and long-time extension effort is needed for the potential of erosion-control practices to be met.

3.46 The gross area of cereal-culture land in the 8 delegations has been estimated at 130,000 ha by Ech Chebeane and Bouratbine. They also estimate 70,000 ha of arboculture. Probably 90% of this land needs protection from erosion by well built, broad-based terraces. This requires long-range continuing policy commitment on the part of the Government of Tunisia and an orderly construction schedule for many years.

3.47 The first step is to establish demonstration units in each delegation. These may serve as applied research units for all the dry-land interventions as well as erosion- and water-conservation demonstrations units. Such parameters as vertical interval for terraces and alternate forms of outlets for discharge from level storage terraces need to be verified for these sites by construction of sets of level terraces. These demonstration units will need to be monitored by the design technicians and by extension workers for several years in order to learn the best combinations of terrace-design standards and management practices. It is urgent that effective long-range erosion-control measures be adopted that protect the land and that suit a system of agriculture that fits the climate, soil, and crop pattern of the area.

Inputs Needed

3.48 The principle restraints to widespread adoption of erosion-control interventions are economic and social. The equipment required to do proper construction work is quite expensive. Cost of construction may require an investment in the order of 100 TD per hectare. Cost per

treated hectare cannot be repaid from dryland crop income now common in the area. Land ownership patterns will be a serious restraint to spread of well-designed terrace systems.

3.49 The Qued Marguellil project illustrates that these restraints can be resolved under Central Tunisian conditions. An early 1960's project demonstrated small impoundment design and construction techniques. Some of these structures have withstood overtopping since completion. Broad-based terrace construction is now to be part of watershed treatment in the Haffouz area in order to protect a major structure now being developed near Kairouan. This project should allow Tunisian technicians to develop their techniques for solving the social restraints to spread of erosion-control practices. (American experts who work with erosion in Central Tunisia should become familiar with projects near Haffoux.)

Training Needed for Personnel

3.50 It is anticipated that participant trainees with professional "ties" to soil conservation and present or future work assignments to the Central Tunisia project be sent for erosion-control training as follows: 2 trainees for 3 months each for each of the 3 years of the project. Anticipated costs would be $66,000 (27,500 TD) each year. (See Appendix Table C-7.)

Increased Outputs Expected

3.51 The increased outputs expected from the erosion intervention alone are marginal. The increased output expected and needed will only come from an integrated dryland system as discussed in Chapters IV and V.

Appendix References

3.32 The appendix to this chapter includes figures and illustrations showing teaching materials used in lectures on soil conservation at the local university (Figures B-6 through B-15). These indicate that Tunisia is already much concerned about the erosion problem and is giving training in the subject matter area. The professional workers in soil conservation are fully capable of absorbing and utilizing advanced, graduate-level training in erosion-control methodology. They are capable of refining design constants to develop appropriate factors for Central Tunisia. A few guide sheets from the University of Missouri are also attached for illustration of some of the numerical factors that may need to be developed for Central Tunisia (see Appendix Figures B-1 to B-5).

IV. PROPOSALS AND REQUIREMENTS FOR INCREASING BARLEY PRODUCTION IN THE PROJECT AREA

Background Information

Current Situation in the Project Area

4.1 Latest information indicates that about 130,000 ha of cereals are grown in the 8 delegations of the project area (Table 1). This includes about 80,000 ha of durum wheat, 10,000 ha of bread wheat and 40,000 ha of barley. The area seeded to cereals varies greatly from season to season depending upon the rainfall conditions. Yield levels in all three types of cereals are very low, ranging from 50-150 kg/ha in Thala, Jedliane, Rouhia, Makthar and Djilma delegations (Table 2). Even though rainfall amounts are relatively low (see Figure IV-1) and highly variable from season to season, these yield levels are extremely low in relation to the potential yield possible under these conditions. Under comparable climatic conditions in Turkey, for example, the average yield of barley ranges from 1,200-2,000 kg/ha. In the Pacific Northwest of the United States under similar rainfall conditions, the yield level of barley ranges from 2,500-3,500 kg/ha.

4.2 The present cultural methods of producing cereals in the project area can best be described as "opportunity" cropping. The farmers of the region apparently decide to plant or not to plant depending upon the rainfall situation during October to December each year. If the rains come early and in sufficient amounts, they will seed their cereal crops. As the season progresses toward December without adequate

Table [illegible] - Land Use Pattern for the Central Tunisia Rural Development Project Area in an Average Year

Type of Land Use	Land Area (ha)	Percent of the Total Area
Cereals	130,000	15.7
Tree Crops	70,000	8.5
Cactus and Shrubs	42,000	5.0
Irrigated Land:		
Exploited	4,700	1.0
Exploitable	6,000	
Alfa Grass & Forests	390,000	47.0
Uncultivated Land	46,000	5.0
Pastures	140,000	17.0
Total	828,468	100.0

Source: CRDA, Kasserine

Table 2 - Yield and Production of Cereals by Delegations in the Central Tunisia Project Area

Delegation	Durum Wheat				Soft Wheat				Barley			
	Expected (Ha)	Actual (Ha)	Yield Qx.	Product. Qx.	Expected (Ha)	Actual (Ha)	Yield Qx.	Product. Wx.	Expected (Ha)	Annual (Ha)	Yield Qx.	Product. Qx.
Thala[1]	16 060	20 500	2.2	45 100	6 140	2 200	1	2 200	10 000	13 000	1.8	24 000
Sbiba[1]	10 150	9 900	1	9 900	1 580	1 600	1	1 600	8 000	7 000	0.5	3 500
Djedeliene[1]	15 030	16 000	2.2	35 200	1 520	1 400	1	1 400	3 000	5 000	2	10 000
Sbeitla[1]	8 020	13 000	1	13 000	1 020	700	0.9	600	7 000	7 000	0.5	3 500
Foussana[1]	7 010	7 530	1	7 530	500	400	1	400	6 000	6 500	0.5	3 250
Rouhia & Makthar[1]	28 000	30 660	5.6	176 700	4 700	5 460	5.6	30 575	5 000	6 540	5.8	39 932
Djilma[2]	-	5 000	3	15 000	-	-	-	-	-	10 000	4	40 000

[1]Dated 1976 - 77

[2]Dated 1975 - 76

Source: CNEA, Tunis

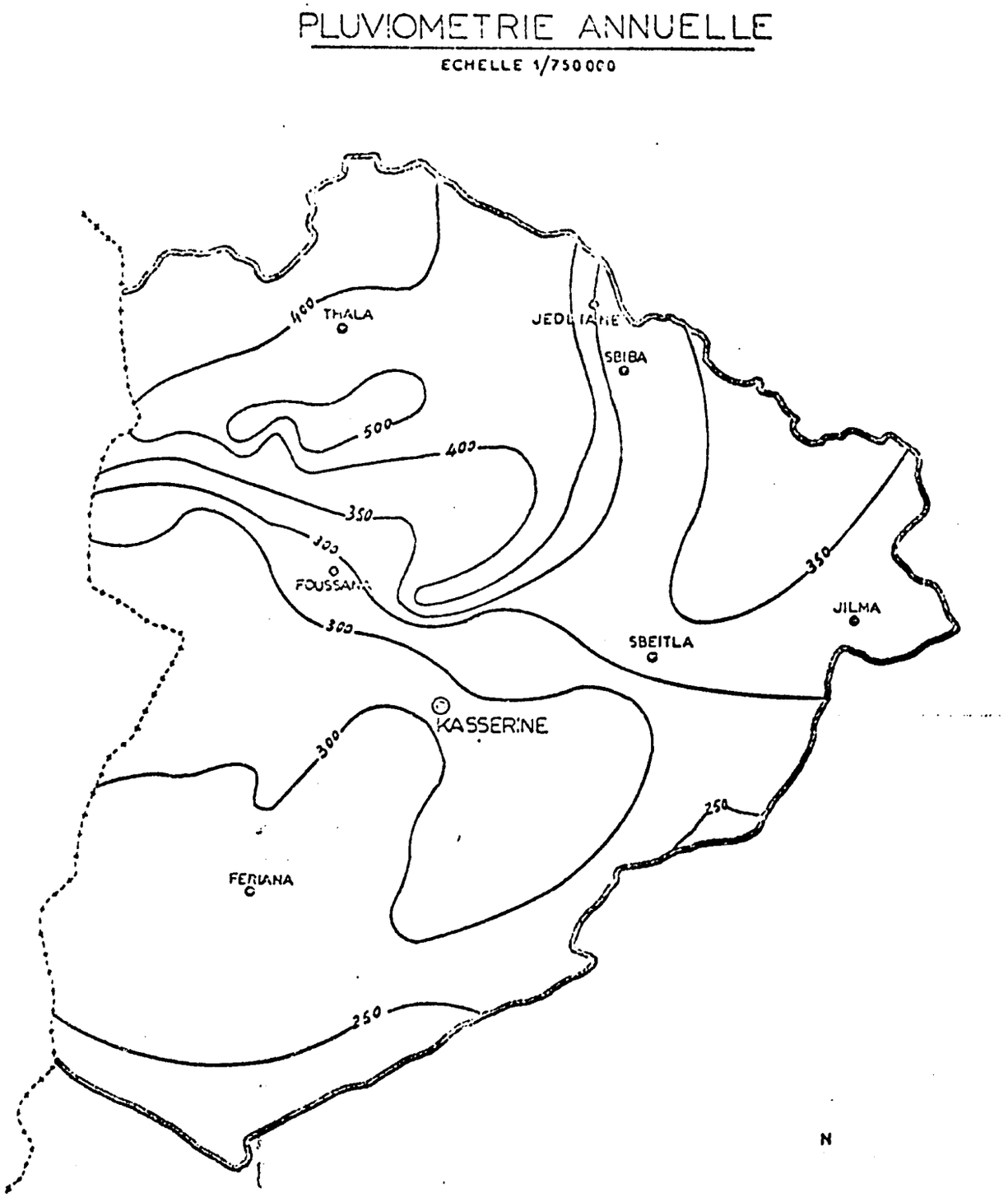

Figure IV-1 - Average Annual Rainfall Isohyetals in Central Tunisia.

rains, more and more farmers decide not to plant. The land is then used for year-round grazing for animals. This "method" of cropping accounts for the wide fluctuations in the area planted to cereals from one year to the next. This system also allows heavy weed growth to occur which extracts most of the moisture out of the soil profile, leaving the crop entirely dependent on timely rains during the crop growth period. The most common method of tillage and seeding is to ground-broadcast seeds over the soil surface and then plow or disk to cover the seeds with a layer of soil. This leaves a very rough, cloddy seedbed with seeds buried to several depths and a considerable amount left exposed on the soil surface. The result is a thin, poor stand of seedlings which is not capable of competing with weeds for the meager moisture and soil nutrients that are available.

4.3 Recent observations in the project area have verified that stands were indeed thin and showed very poor plant development. The stands observed throughout the project area ranged from approximately 50-70 plants per M^2 with usually one, sometimes two, tillers. An adequate stand in areas with similar climatic conditions is usually 100-150 plants per M^2 with an average of about 2 tillers per plant. This indicates that the number of grain-bearing spikes in the project area is about 70-90 per M^2 as compared to an adequate level of 200-250 spikes or heads per M^2. When the stands are thin, larger spikes and seeds to compensate for low plant numbers can be expected. However, in the project area, the barley and wheat spikes were very small. This could be due to a number of factors including nutrient deficiencies, especially low phosphate levels, late planting dates, heavy weed population, and

poorly adapted varieties. It is probably due to a combination of several of the above factors.

4.4 Even though the rainfall is relatively low and erratic in this region and the soils shallow in parts of the area, it appears that the potential yield on the average is at least 4-5 times greater than is presently being achieved. In areas with comparable rainfall amounts and soils of 1 meter or greater depth, average yields under adequate management techniques range from 1500-4000 kg/ha. The seasonal fluctuations in yield are generally large even under good management, but the actual yield levels are considerably greater than presently achieved in the project area. The potential yield of cereals in a given area is dependent on the amount and distribution of rainfall, temperature, and soil resources (depth, type, fertility). The actual yield achieved in a given area is determined by how well one manages the crop in relation to the climatic and soil resources. The more adverse the climatic and soil conditions, the more critical good management techniques become.

4.5 Essentially no cereal production field research is available in the project area. Most field trials conducted by the Office of Cereals and other research groups are in the higher rainfall zones of the north. Little or no effort has been exerted to date to develop cereal varieties (barley or wheat) for the drier zones of Tunisia. As far as is known, there are no field trial results in the project zone on varieties, fertilizers, planting dates and rates or soil management techniques. Without these kinds of data it is almost impossible to mount an effective extension effort to increase the yield level of cereals. This information must be developed in the project area and

then production systems can be devised that are feasible and acceptable to the farmers of the region. An extension effort without sound information to extend to the farmers of the region is doomed to failure from the beginning. A sound field research program on varieties, fertilizers, planting methods, seedbed preparation and tillage methods is essential to increasing the yield levels and training extension workers in good cereal production methods.

Goals for Improving Cereal (Barley and Wheat) Production in Area

4.6 The most immediate goal for improving cereal production in the project area should be to begin a series of applied field trials on varieties, fertilizers, planting methods, weed control, dates and rates of planting, and tillage techniques. Extension agents stationed in the vicinity of these trials should assist in conducting the field research in cooperation with the research staff so that they can become more proficient and confident in their efforts to extend the results to farmers. The individual elements in the production system that show substantial yield increases could be introduced to the farmers of the area as the information is developed. For example, if a more productive, adapted variety is identified in the field trials from the existing breeding material, it could be immediately increased and introduced to the farmers. If seed bed preparation and mechanical seeding showed striking increases, then these elements could be introduced. It would be difficult and time consuming to develop a complete package of practices before introducing parts of the package to farmers. In addition, it is unlikely that many farmers would be ready to accept a complete

change of practices at one time, whereas individual components might be acceptable.

4.7 The long-term goal for increasing cereal production in the project area should be to develop a complete package of practices adapted to the climatic zones of the region. This will involve a continuing field research program in the area on the following items:

1. Cereal breeding (barley and wheat) directed toward adapted varieties for dryland conditions;
2. Continued variety testing of current materials throughout the region;
3. Soil feritility and fertilizer trials;
4. Agronomic trials (date and rate of seedling, seeding methods, weed control, crop rotation, etc.);
5. Soil management and moisture conservation trials (tillage techniques, fallow-crop rotations, seedbed preparation, erosion control).

4.8 The trials recommended above will help to determine the actual yield potential of the dryland cereal zones. Additional work will be required to adapt these practices to the individual small farmer of the region. Many other constraints may affect the farmers' decisions to adopt new technology, especially the very small farmers. The availability of credit, improved seeds, fertilizers, herbicides, machinery, prices and marketing opportunities will all have an effect on the farmers' decision to adopt new technology. The key is to make the technology available with suitable alternatives so he can make a rational decision. The new technology must have been demonstrated to him in his region before a decision to adopt the new practices will be made.

Constraints to Increasing Production

4.9 The most obvious constraint on cereal (barley or wheat) production in the project area is the production system itself. The so-called "opportunity cropping" system of only planting cereals when the season "seems" right, i.e., adequate rainfall occurs sometime between October and December, is really no system at all. It is an attempt to exploit the land resources only when the opportunity appears favorable. The problem is that favorable rainfall in one part of the season does not guarantee a crop at harvest time. Because of poor tillage and seedbed preparation, heavy weed populations, low fertility, poorly adapted varieties, and thin stands -- even if climatic conditions remain favorable -- the yield level is still very low compared to the potential yield possible. The present system must be changed if progress in increasing yields is to be made.

4.10 A second constraint is the lack of production research data in the project area. Without such data, it is practically impossible to devise a cropping system best suited to local conditions. Techniques that are successful in other dryland areas are known but they must be tested under the local conditions. There is also the matter of convincing the researcher, the extension agent, and the farmer that the new methods "talked about" actually work in the region. Sound, applied field research is a powerful tool for training, demonstrations, and extension work which, as the best practices are determined, increases the ability and confidence of each person involved.

4.11 Thirdly, the extension staff of the region must be involved in the field research program from the beginning if they are to carry

the message to farmers. The usual roadblock from research to application in the farmer's field occurs between research and extension activities. The researcher sends the information to the extension agent who either may not understand the results or doesn't believe in them and lacks confidence in his ability to convey the results to the farmer. By being involved in the actual field research and observing the results, the extension agent and researcher can remove this "roadblock."

4.12 A fourth constraint relates to marketing and pricing policies. If increased production is achieved and cereal grains are produced above the immediate need of the farmer's family, a means for profitable marketing must exist. The price structure must be such that the incentive to produce more cereal grain exists. This particularly is true if increased barley production is desired. At present in the project region, according to recent statistics, durum wheat hectarage is about double that of barley (90,000 vs. 45,000 ha). This is true for 6 of the 8 delegations, the only exceptions being Sbiba and Foussana delegations where the ratio of durum wheat to barley is about equal. Barley, under relatively good management, is generally a more stable crop in terms of yield under dryland conditions. If barley production is to be stressed, then the price between durum wheat and barley should be about equal. Under these conditions, the hectarage would probably shift toward barley production in the dryland regions.

New Technologies to be Introduced

4.13 To improve the production of cereals (barley and wheat), the following practices must be developed and introduced in the project area:

1. Cereal variety testing and breeding;
2. Improved cultural practices;
3. Improved fertilizer use;
4. Improved weed control (during both crop and non-crop period); and,
5. Improved soil management and moisture conservation practices.

Cereal Variety Testing and Breeding

4.14 The testing, selection, increase, and distribution of better adapted barley and durum wheat varieties suitable for the dryland areas is perhaps the most immediate way to have an impact on production in the project area. It should be emphasized that introduction of new varieties alone will not solve the problem of low productivity under dryland conditions. It does, however, offer an avenue to introduce new technology. Exchanging seeds of an old variety for seeds of a new variety does not involve a change of production methods. It is merely a substitution of one element of production for another. If the costs are not too great, farmers are usually willing to make the substitution. Introduction of a well-adapted variety should give at least a slight increase in yields but perhaps not as great as expected. One should be careful about "overselling" the importance of a new variety so as to avoid disappointment if substantial increases are not achieved. In a good dryland production system, a well-adapted, productive variety is an essential ingredient but must be combined with other elements of the package to give the desired increase. Perhaps the current varieties and lines do not include any types that are adapted for dryland conditions. In this case, immediate steps should be taken to obtain types from

outside sources for testing in the project area. Cereal variety trials should be conducted in every delegation where climatic and soil conditions are different. A strong barley breeding program should be encouraged and well supported in order to supply to the farmers the best possible variety for their conditions.

Improved Cultural Practices

4.15 Thin, weak stands appear to be one of the main factors responsible for the low yields in the project area. This could be overcome perhaps by better seeding methods, e.g., drill seeding instead of broadcast seeding. The variety trials could be combined with seedbed preparation and mechanical seeding using duplicate trials at the same location or a split-plot design utilizing the two methods of seedbed preparation and two methods of seeding (drill vs. broadcast). Other cultural practices that need attention are:

1. Rate of seeding (drill seeding should require less seeds/ha) and
2. Date of seeding (better seedbed preparation may allow earlier seeding).

Variety tests also might be conducted under "poor management" conditions.

Improved Fertilizer Use

4.16 Little or no fertilizer appears to be used in the project area on cereals. The nature of the climate and soils would lead one to suspect nutrient deficiencies in the cereal crop, especially for phosphates. A series of simple phosphate and nitrogen treatments should be established to determine the response to fertilizer application. The

phosphate fertilizers can be drilled with the seed at planting but nitrogen should be applied separately to avoid damage to emerging seedlings. If there are indeed nutrient deficiencies in the cereal crops of a serious nature, the introduction of other practices, such as new varieties, better seedbed preparation, and better seeding methods, may have little effect. The identification of the major limiting factors on yield is the key to developing a productive cropping system. There are usually no reliable "short-cut" methods in developing a sound dryland cropping system. The types of field trials described above should be well-designed, replicated, statistically sound experiments so that the data can be properly evaluated without bias.

Improved Weed Control

4.17 Under dryland conditions, it is generally assumed that any moisture or nutrients used by weeds reduces the yield of the crop by a proportionate amount. Whatever is removed by weeds must be replaced in order to be available to the crop. It is particularly critical that weeds be eliminated in the early stages of crop growth. Many previous studies have shown that weed competition in the early stages of crop growth (seedling, tillering, early jointing) reduce yields to a much greater extent than during the latter growth stages (late jointing, heading, grain filling). Careful observations of the weed species and population numbers should be made in all trials so that the proper herbicides can be selected for future weed control trials. Better tillage methods and seedbed preparation may eliminate a large part of the weed problem. However, it is often found that improved soil management and seedbed preparations that enhance crop growth also enhance

weed growth. The improvement in crop growth due to improved varieties, fertilizers, cultural practices, etc. could be lost due to excessive weed growth in the crop.

4.18 The first priority in the weed-control research is to identify the magnitude of the weed problem, the species present, and the probable losses due to weeds. Each researcher working on the dryland cereal production system should be aware of the potential weed problem and report to the person responsible for carrying out weed-control measures. Weeds are important in both the crop and the non-crop (fallow) periods. The present use of cereal lands for heavy livestock grazing on the aftermath and weed growth during the non-crop (fallow) period is undoubtedly having an effect on the possible moisture storage in the soil profile which could be used later on by the cereal crop during the cropping period. Control of weeds in the fallow period is discussed in the following section.

Improved Soil Management and Moisture Conservation

4.19 In many areas of the world where cereals are produced under dryland conditions, such as in Central Tunisia, a two-year fallow-crop rotation is used. This system involves storing moisture in the soil profile during the first year after harvest which is then used by the crop during the second year along with the rainfall received during the cropping period. The fallow-crop rotation appears on the surface to be an inefficient method to use land and moisture resources. Soil moisture storage during the fallow or non-crop period usually ranges between 15% and 35% of the total rainfall received, depending upon temperature, rainfall distribution, and soil depth. This appears to

be relatively low moisture storage efficiency, but the soil moisture in profile is available to the cereal crop at relatively critical periods of growth. This results in relatively stable crop yields on a biennial basis and in many cases increases the overall water use efficiency for grain production. The conditions in Central Tunisia appear conducive to the fallow-crop system and should be investigated as a possible cropping system.

4.20 In a fallow-crop system, the cereal lands could be used for grazing for a portion of the fallow period, but should be kept weed-free during the late spring, summer and early fall prior to planting. A series of preliminary trials should be conducted comparing the annual and fallow-crop rotation (biennial) system to determine the system best suited for the project area.

4.21 Soil management research also should be conducted on time of tillage, tillage implements, soil moisture storage, and weed control. Research and training in dryland agronomy is limited to only a few areas of the world. Most of the basic studies in this area have been developed at a few universities in the western United States and in several universities in Australia. It is strongly recommended that advanced training be provided for at least two Tunisian scientists (1 at MS and 1 at PhD level) in dryland agronomy. The possible training sites are Colorado State University, University ~~of Nebraska,~~ Oregon State University, and Washington State University. Technical assistance in the form of an experienced foreign adviser is strongly urged in the beginning of a soil-management and moisture-conservation program.

Development of a Regional Training and Research Center of Cereal Breeding and Crop Production for Central Tunisia

4.22 The lack of information and definitive data on the soil resources, varieties, crop yields and response of crops to climatic conditions in the project area is a serious hindrance to further development. There is a great need for applied field research to determine the best combination of cropping practices for the region.

4.23 The Agricultural Training Institute at Le Kef (Ministere De L'Agriculture, Ecole Superieure De Grandes Cultures) could well serve the project area with a sound applied field research program if adequately equipped and staffed. The Le Kef Institute has adequate physical facilities to house staff, laboratories, and trainees and to operate as a regional research center. In addition, a 1500-ha. block of land is available for use as a field research and training facility. The Institute is under the direction of a well-trained, enthusiastic director, Dr. A. Daaloul, who envisions the role of the Le Kef facility as having three primary objectives:

> The first objective would be to train higher technicians as specialists in field crop production. The trained technicians would be qualified to serve as extension agents, to work in management of state farms, to work in seed companies, and to serve as technical assistants in other research institutes.
>
> As a second objective, Le Kef could become a regional applied research center to serve the agricultural needs of Central Tunisia. The main research responsibilities would be in three areas: a) cereal breeding - barley, durum wheat, bread wheat; b) production agronomy - all crops both dryland and irrigated; c) soil fertility and soil management. The proposed overall staffing pattern for the Institute is shown in Appendix Table C-1, as prepared by Dr. Daaloul.

The third objective would be to provide a facility and program for intensive training of extension agents. This training could involve special courses, workshops, seminars, etc., conducted at Le Kef, as well as supervised, on-the-job instruction for extension workers assigned to the Central Tunisia project area. Each senior staff member would have teaching as well as research responsibilities.

4.24 When the Institute is fully staffed (as shown in Appendix Table C-1) with bright, young, well-trained agricultural scientists and fully equipped, it is envisioned to have great positive impact on agricultural development in the Central Tunisia region.

4.25 The greatest immediate needs of the Institute in order to be of service to the project area in the near future include complete facilities and equipment for a soil-testing laboratory at the Institute, field equipment and transport for soil fertility and agronomic field studies. Detailed lists of equipment, transport and supplies are shown in Appendix Tables C-2, C-3 and C-4.

4.26 An additional need is advanced training of several Tunisians in the applied research fields shown in the proposed staff list (Appendix Table C-1). This advanced training should begin as soon as possible. Additional technical assistance also will be needed in the form of U.S. technicians to help set up the soil-testing facility and to begin the field work in dryland production agronomy. The soils technician could probably work on a short-term assignment once the soil laboratory equipment arrived and help to get it in operation. The dryland agronomist could either be a long-term (two-year) assignment or could make several trips during the season at critical periods of the field work. Other short-term technicians may also be needed as the staff are assigned in the areas of: farm management economics, weed control, farm machinery and experiment station development, horticulture,

and irrigation and conservation engineering. These consultants would be valuable to insure that each phase of the applied research program begin with a sound, strong program and to help assure a coordinated and integrated systems approach in working with farmers in the project area.

Training and Technical Assistance in Applied Crop Production and Related Research for Central Tunisia

4.27 The future success of the Applied Research Center at Le Kef will depend upon the professional competence and dedication of the Tunisian personnel assigned. Sound training for staff members may be arranged through academic degree programs for carefully selected young Tunisians in U.S. universities, through shorter-term technical training for some specialities, and through USAID consultants for short-term and long-term assignments. Suggested personnel for these assignments are outlined below.

Proposed Training for Tunisian Specialists Abroad

Type of Training	Training Level	MM Required
1. Soil Fertility and Management	PhD	36
2. Crop Production Agronomist (Dryland)	PhD	36
3. Farm Management Economist	M.S.	24
4. Weed Control Specialist	M.S.	24
5. Farm Machinery & Experiment Station Manager (Note: CIMMYT, Mexico has a special course of 6 months in experiment station management. Candidate could go to CIMMYT first and then continue for M.S. training in Farm Machinery at a U.S. university.)	M.S.	30
6. Irrigation and Conservation Engineer	M.S.	24
7. Extension Training Specialist	M.S.	24

4.28 The above training is considered minimal for Tunisian staff members for the positions indicated. The need for initiating this training promptly is obvious in order to develop a competent Tunisian staff as soon as possible. In the interim, a heavier concentration of consultant help--along with some short-term technical and management training for Tunisians in U.S. universities--may help expedite agricultural phases of the Central Tunisian project. For this short-term participant training, the U.S. universities selected should be chosen carefully so that conditions similar to those in the project area can be observed and evaluated as part of the training program.

Training Through USAID Consultants

4.29 Long- and short-term AID technical and scientific personnel may be selected to assist Tunisian counterparts in developing adaptive field research programs in Central Tunisia. This on-the-job type training for Tunisian staff members in-country may complement the longer-term academic training earlier described. Types of consultants needed and the man-months of time suggested are outlined below.

	Man-Months Required			
Long-Term Specialties	1979	1980	1981	Total
Project Coordinator				36
Short-Term Specialties				
Crop Production Agronomist (Dryland)	6	3	1	10
Soil Fertility-Soils Laboratory Specialist	5	3	2	10
Farm Machinery and Experiment Station Management	5	3	2	10
Farm Management Economist	2	3	1	6
Weed Control Specialist	3	2	1	6
Irrigation and Conservation Engineer	2	2	2	6
Extension Training Specialist	2	2	2	6
	25	18	11	54

4.30 Both long-term and short-term consultancies seem to have unique roles to play in the Central Tunisia agricultural development program. In subject matter fields in which available Tunisians already have basic and advanced training, short-term AID consultants may well fill the need for on-the-job training for Tunisian counterparts, for helping initiate new projects, for "trouble shooting" during unforeseen difficulties, and for helping evaluate and adjust on-going programs. An example is in wheat and barley breeding--fields in which Dr. Daaloul and Moncif Harrabi already are trained and competent. Another is in agricultural engineering, a field in which many Tunisians have had basic training and experience in several phases of engineering development.

4.31 A case may be made, however, for longer-term assignments in some specialties indicated above. For example, dryland farming involves many complex relationships and technologies and several universities in the U.S. have had comprehensive research and training programs in this specialized type of farming for many years. Since dryland farming involves close timing of many operations, season-by-season, and little margin for errors, it seems wise to have a specialist in dryland farming to work with the Le Kef staff for the first two years while a Tunisian student is getting his essential academic training in this field.

4.32 Likewise, short-term consultants can assist in setting up the soil-testing laboratory and in training Tunisians to operate it. But the value of soil tests in guiding the development of more productive and profitable farming systems for small farmers in the project

area can be realized only by correlating the tests with field trials and observations throughout the year. A two-year assignment for on-the-job guidance in this work seems necessary while a young Tunisian, such as Mr. Habib Halila, is getting the advanced training needed for assuming this responsibility in the longrun.

4.33 The mobile equipment units needed for the applied research in different delegations in the project area are unique for various operations and require special skills in operating, servicing, and management. Even more demanding is the job of coordinating and managing the use of land, equipment, labor, and other resources in order to facilitate the work of the various research scientists involved, hence the urgency in getting a young Tunisian started in his training at CIMMYT and an associated university. In the meanwhile, the longer-term consultant seems desirable.

4.34 For most effective work, all these long-term consultants should be located at Le Kef in order to work closely with their Tunisian counterparts.

Calendar of Events for Implementing Interventions

4.35 Many projects often lag behind projected goals because the training and equipment procurement component is out of phase with the action program. It is strongly recommended that the training and equipment and supplies component be initiated as soon as possible so that these elements are placed to begin the action program in the field.

Year 1:

1. Select and send Tunisian participants for advanced training in specialty areas listed in Appendix Table C-1.

2. Order equipment and supplies for a) soils laboratory, b) soil fertility and agronomy field trials (2 mobile units), and c) cereal variety testing and breeding trials (2 mobile units). See Appendix Tables C-2, C-3, C-4 for specific items.

3. Begin limited field trials on barley varieties (Moncif Harrabi) fertilizer trials on barley (Habib Halila) in project area. The two young scientists presently with the Office of Cereals, Tunis, indicated that they probably could conduct 1 or 2 trials in the project area nearest to Le Kef in 1978-79. Expanded work in project area is contingent on receiving additional equipment specified in Item 2 above.

4. Collect long-term climatic data (rainfall and temperature) from as many sites as available for future reference for field studies (assemble at Le Kef Institute).

Year 2:

1. Set up soil analysis lab provided equipment has arrived for Soil Fertility and Soil Analysis and the AID consultant (long-term) has arrived to assist setting up and operating soils laboratory.

2. Expand cereal variety testing and breeding program in the project area using mobile equipment units.

3. Expand soil fertility and agronomic trials on cereals (barley and wheat) in the project area. AID consultant (long-term, crop-production agronomist for dryland) should arrive to help set up equipment and initiate field trials.

4. Long-term AID technician in farm machinery and experiment station management should arrive to assist in the use of machinery in the project area and set up management plan for Le Kef experiment station.

Year 3:

1. Expand soil sampling and analysis throughout the project area.

2. Select barley and wheat varieties from testing program for increase and distribution to project area farmers.

3. Continue soil fertility and agronomic studies--select best treatments for crop production extension program.

4. Tunisian participants in farm management economics, weed control irrigation and conservation engineering, and the extension training specialist should return from advanced training. Short-term AID consultants in specialties above should arrive to assist in setting up field research programs.

5. The extension training specialist and short-term AID consultant should set up an extension training program in improved dryland crop production for extension workers assigned to the project area.

*Year 4:

1. Tunisian participant trainees in dryland crop production and soil fertility and management return.

2. Extension training specialist and field research staff initiate project area-wide demonstration program to introduce newly developed technology in varieties, fertility, cropping systems and weed control in dryland cereals.

3. Long-term AID consultants terminate after sufficient overlap with Tunisian counterparts.

*Year 5:

1. Follow-up visits by short-term consultants to evaluate progress of programs and assist to redirect if necessary.

2. Phase-out of technical assistance.

Summary and Evaluation of the Impacts of this Intervention

4.36 Earlier data presented in detail for this proposed intervention highlight the significance of cereal production (barley and wheat) to the welfare of the small farmers in the dryland areas of Central Tunisia and the potential for improving future productivity.

*While USAID assistance is scheduled only through 1981, projections are extended for two years longer to indicate how the transition can be made to continuing the longrun development with Tunisian staff only.

Key factors which condition any kind of economic evaluation are summarized below.

1. Cereals are widely grown in the 8 delegations of the Central Tunisia Project area--an estimated 102,590 ha. of durum wheat, 11,760 ha. of soft wheat, and over 55,000 ha. of barley in 1977.[1] Probably more than 15,000 small farmers in the area are engaged in cereal production, both for family consumption and as a source of cash income.

2. Yields of wheat and barley are extremely low, even for climatic and soil conditions which prevail in the area. In 1977, the yield of durum wheat on dryland was estimated at about 3 Qx. per ha. in the entire project area; less than 2 Qx. per ha. outside of Rohia and Maktar delegations where rainfall is highest. Soft wheat produced little more than 1 Qx. per ha. in the drier delegations with a range from less than 1 Qx./ha. in the Sbeitla delegation to 5.6 Qx./ha. in the Rohia/Maktar area. Barley yields averaged less than 2 Qx./ha. except in the Rohia/Maktar delegations where it was about three times greater.[2]

3. Cereal production methods are primitive and ineffective and small farmers now lack the equipment, "know-how," inputs, financing and incentives to make major improvements. This is the primary constraint but an associated one is the complete lack of applied research on which to base production improvement in the area. Coupled with the applied research deficiency is the lack of organization and trained personnel to conduct a practical, field-oriented and family-centered extension program with low-income, dryland farm families in the area.

4. The potential for increasing cereal yields above present levels is very promising if the above problems can be overcome. Yields of wheat and barley in dryland areas in the U.S., in Turkey, and in other countries are as much as ten-fold greater than in Central Tunisia, even though rainfall, soils, and other physical conditions are similar.

5. Personal assistance--in the form of instruction, supervision, supplies, financing, custom services, etc.--must be made available to small farmers to help them change from traditional methods to systematized production programs. First, however,

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[1] Data derived from An Assessment of the Agricultural Potential of Central Tunisia - Evaluations and Recommendations by a University of Missouri Consultant Team - April, 1978, pages 136, 137 and 138.

[2] Ibid., pages 136-138.

they must be "shown how" with professionally-conducted applied research and follow-up demonstrations on farms similar to their own and in their own neighborhoods.

4.37 The following observations and projections are based upon the assumption that a sound program of applied research and extension can be formulated, with adequate personnel and supportive resources to implement the recommended production systems with individual farmers in the area.

Purpose of Intervention (Quantified)

4.38 The purpose of this intervention is simple--to help small, dryland farmers increase yields, production, and farm income from improved cereal production. Implementing the program is much more complex and time-consuming. Even more difficult is the task of quantifying and evaluating the consequences of the intervention over a period of years.

4.39 As indicated in the earlier calendar of events, the first year of the approved program will be needed for acquiring the necessary equipment, supplies, and initial personnel training. At the end of the second year, initial data from carefully located field trials should become available to serve as a guide for the next year's testing of more complete production systems. By the end of the third year, information, trained personnel, improved seeds and other supplies, and financing should be available for launching a wide-spread demonstration program in most of the sectors of the 8 delegations.

4.40 In summary, the purpose of the first three-year intervention is to build a sound foundation for a longrun improvement program. Without such, no program can be expected to succeed over time.

Outputs Expected

4.41 As indicated above, most of this three-year intervention will be preparatory in nature. Increases in physical output--in terms of quintals of wheat and barley, for individual farmers and for the project area--are expected to be significant.

4.42 However, the benefits from this preparatory work, if well done, should really unfold during a second five-year period. In terms of cereal yields and production, achievements such as the following might reasonably be expected.

4.43 Increase in barley yields and production. Dryland barley yields on individual farms may be expected to increase as much as 400%--from 2 Qx./ha. to 8 Qx./ha. (On well-managed farms, the increase might be even more spectacular.) For the area as a whole, however, an average increase of 100% (from 2-4 Qx./ha.) may be a more reasonable estimate since only 25-35% of the farmers might adopt the new production system within this time frame.

4.44 Total barley production--with the 2 Qx./ha. increases in yield and 55,000 ha. planted as estimated for the area in 1977--would double, ar increase from 110,000 Qx. to 220,000 Qx. The value of the added production of TD 4.000 per Qx. would amount to an additional TD 440,000 income for the project area.

4.45 From a national viewpoint, this added production--which could expand over time in both hectarage planted and yields--would provide an in-country source of high-energy concentrate feed to support the expanding livestock industry, and thereby reduce the dependence upon imported grain feeds. This contribution might be doubled if one-half of the

1977 wheat hectarage (amounting to 57,000 ha.) were shifted to barley production. This kind of shift is often recommended since the dryland conditions seem better suited for barley production.

4.46 Increases in wheat yields and production. Application of the proposed intervention is expected to increase wheat yields about the same as those for barley, percentage-wise. The increase in total production per hectare also would be similar since the starting yields are about the same. The change in total production for the area would depend upon shifts in planted hectarage between barley and wheat, as earlier illustrated.

4.47 Effect on individual farm units. Increases in production of wheat and/or barley resulting from adopting improved production systems on individual farms would be more impressive on a relative basis.

4.48 Using barley as an example and assuming a dryland farming system with 10 ha. of barley per year, the average increase of 2 Qx./ha. in yield would provide an additional 20 Qx. of barley produced. At TD 4.000 per Qx. this would add TD 80.000 to the family gross income. The good manager who achieves a five-fold increase in yield (from 2-10 Qx. per ha.) would produce an additional 80 Qx., with an added gross income of TD 320. While these amounts may seem small, they are quite significant to small farmers in the area.

Inputs Needed

4.49 Two major types of inputs are needed for this intervention: 1) the initial capital investments required for equipment and facilities, for participant training and for consultant assistance; and 2) the operating inputs--labor, supplies, operating capital, etc.--needed as the program is implemented.

4.50 The physical facilities needed are itemized in detail in Appendix Tables C-2, C-3, and C-4. In Appendix Tables C-5 through C-8, preliminary cost estimates are summarized for the above facilities and for participant training and consultant assistance. These inputs represent capital investments, most of which would be committed during the three-year time period.

4.51 Most of the operating inputs and associated variable costs would not be required during the initial three-year time period. Any quantification of these for a later time period would depend upon the extent of the program and the prevailing prices in the later years. Useful predictions cannot be made at this stage.

Analysis of Costs and Returns
Per Farmer Served

4.52 In order to perform this type of analysis, several kinds of data are needed, such as the following: 1) the total capital investment required for the intervention; 2) the number of farm cooperators served; 3) the value of the added production to the farmers served; 4) a computation of the annual fixed costs associated with the investment capital committed, related to some arbitrary time period; 5) a calculation of the total costs (fixed and variable) allocated among the total number of farmers benefited; 6) a determination of the annual net returns from the intervention (the value of the added production less the added total costs); and 7) the allocation of the net returns among the farmers served.

4.53 As earlier explained, such an evaluation is not feasible and realistic for this intervention within the three-year time frame.

Estimated "Cost Effectiveness" of the Intervention

4.54 As in the case of the cost-return analysis, sufficient performance data will not be available within the three-year duration of this intervention to make a realistic cost evaluation.

V. PROPOSALS FOR ESTABLISHING PILOT STUDY/ DEMONSTRATION AREAS IN CENTRAL TUNISIA

Introduction

5.1 Earlier sections of this report contain detailed recommendations for specific interventions for the Central Tunisia Project Area. These include shallow- and deep-well irrigation, erosion-control and rainwater management and improved dryland cereal production. Each intervention includes a number of improved technologies, each of which is essential for successful implementation. However, each new technology, applied alone, may have little or no value in the improvement of productivity and income. An example or two will illustrate this response.

5.2 Field trials may identify a variety of barley which is far superior to those currently grown in the area. However, if the seed is broadcast by hand and either plowed or disked in (as currently done) without weed control and proper fertilization, the yield may be no higher, perhaps even lower, than that of the varieties presently used.

5.3 Likewise, the proper construction of level, storage-type terraces on a long slope may greatly reduce erosion losses and help conserve moisture for crop and pasture production. However, if the terraces are poorly constructed with improper outlets and are not protected from water runoff from steep land up-slope, the entire system may fail, with intensified gully erosion, from one severe rainstorm.

5.4 In a similar way, the proper adoption of one new intervention, such as those mentioned in Paragraph 5.1 above, may fail to contribute most to the productivity and income of a small-farm family in the project area when applied alone. Only when new technologies and interventions are combined and coordinated into a complete system of farming, which suits the resources and needs of the farmer and his family, can the full potential of the improvements be realized.

5.5 The purpose of the pilot study/demonstration area is to assist farm families in a selected location in planning new systems of farming best suited to their own resources and needs. Since each farm and family unit is unique in some ways, the system of farming should be planned and developed individually with each farmer in the study area. Most of the individual technologies--and "packages" of them essential for a particular intervention, such as barley production--and the procedure for farm planning would be completely new to the farmers involved. Therefore, well-trained extension workers would need to be available to work closely with the individual farmers in planning and selecting most suitable farm plans and in developing them, step-by-step, over a period of years.

5.6 Obviously such assistance could be provided to farm families outside a project area. And such a procedure would be highly desirable over a period of time as extension workers in each delegation gain experience and confidence in working with the complete farm and family as a unit. Experience elsewhere has shown that a new system of farming, embracing the coordination of a number of improved technologies, often leads to a spectacular increase in production and

income. Such a developed system motivates neighboring farmers to adjust their own systems of farming in a similar way.

5.7 The proposal for initiating the improved farming systems with a group of farmers in a project area is made for several reasons. First of all, some interventions--such as water management in dryland areas for erosion control and moisture conservation and controlled grazing for improved range management--require the concerted efforts of all the farmers within a locality. Also, extension workers can assist several farmers in one locality more efficiently over a period of years. The motivational effect of several working together toward a common goal also is an important factor. Finally, the educational value of having numerous method and result demonstrations of improved technologies coordinated in complete farming systems in one area can form an impressive pattern for the longrun development of farming in the project area. Each successful farm unit automatically becomes a demonstration unit, even though not so designated, to influence those who adopt changes more slowly.

5.8 Suggestions for selecting sites for project areas, for organizing work, for implementing the program, and for evaluating and using the results will be given in the following sections, along with an estimate of the facilities and personnel required.

Site Selection

5.9 For longrun development, two different types of areas might be selected, listed in order of priority as follows: (1) dryland farming areas (no potential for irrigation); and (2) combination dryland-irrigated areas.

Dryland Farming Areas

5.10 Selection of a dryland farming area for the initial pilot study effort is recommended for several reasons. First of all, a high percent of the very low-income farm families are located in dryland areas where irrigation water is not available. Secondly, erosion control and rainwater management are crucial factors in restoring and maintaining productivity in these areas and, to be effective, these innovations must be integral parts of complete farming systems. And, thirdly, alternative uses of land and other resources are much more restricted and planning effective farming systems is more difficult.

5.11 Actual selection of a site for the initial study area should be made by the Office in cooperation with local authorities, the farm families involved, and the local leaders. Dryland areas in either Djilma or Jedlianne seem to merit first consideration.

5.12 Because of complexities of ownership and operating units in the dryland areas and of the extensive construction work required for erosion control, a site on GOT land (perhaps Forestry Service land) might be selected initially. Several factors should be considered in choosing the exact location, such as follows:

1. Select an area large enough for 15-20 complete farm family units, each consisting of 30 or more has. of land suitable for crop production and improved pasture;

2. To the extent possible, choose land with long, regular slopes, 2-6% grade, to allow for construction and farm units somewhat as illustrated in Figure III-1; and

3. Try to locate an area typical of large areas of dryland in the different delegations to provide applicable patterns for future expansion.

Combination Dryland-Irrigated Areas

5.13 As a second priority location, an area where both irrigated and dryland can be made available to each farm unit is suggested. At least two alternatives are possible:

1. One logical location would be in connection with a new irrigation perimeter around one of the deep wells available in the area for development. In such case, land redistribution would need to provide for equitable distribution of both dryland and irrigated land for each farm unit--perhaps 1-2 has. of irrigated land each and 20 or more has. of dryland.

2. Another location, and one which probably could be initiated more quickly, could be an area consisting of a group of small farmers with shallow wells (either existing or new) and with both irrigated and dryland included in their farm units.

5.14 Details of organizating the work and development of the pilot study/demonstration area (subsequently referred to as the project area or the area) selected would vary somewhat with the location and the nature of the resources and families involved. Two factors, however, should be given uppermost consideration--the necessity for an inter-disciplinary approach and for involvement of the local people from the beginning.

5.15 The inter-disciplinary group should include members of the staff of the Central Tunisia Office, the applied research staff serving the area, extension workers, Soil Conservation Service staff and technicians, and expertise available from other related institutes and agencies. One extension specialist, with farm management training and experience, should be assigned to work full-time in the area for work later described. A short-term consultant, with experience in farm planning and management work, should be provided to work with

the extension specialist during the initial planning work and later as the program is implemented.

5.16 The Office staff would be responsible for the project area and should maintain close working relationships with the delegation officials and with the Secteur and farm leadership within the area. Farmers in the area should be kept fully informed about all stages of development and make the final decisions relative to their own farming systems. The Office also should make necessary arrangements with the applied research and technical staff at Le Kef for essential technical training and supervision for extension specialists and their assistants assigned to the area. Such coordination will help assure success with the longrun development program.

Steps for Implementation

5.17 Since development of a pilot study/demonstration area is a longtime process, it should proceed in a logical, step-by-step manner. Consideration should be given to such steps as the initial preparatory work, individual farm planning, supervised development of plans over a period of years, providing inputs and custom services, and maintaining a system of on-going records.

Preparatory Work

5.18 After a site is selected for a dryland project area, as an example, it is suggested that all construction for the complete water management system (diversions, sediment basins, water storage, terraces, etc.--as described in Chapter III of this report) be completed before the farm units are actually arranged and assigned to farmers. Plans

for the individual farm units, from the standpoint of size and general arrangements, should be formulated in advance as part of the overall design for the project. Specific plans for the farm units should be delayed until each farmer can assist in their formulation.

5.19 After site selection is finalized, short-term AID consultants--including an agricultural engineer and a farm management specialist, both with longtime experience in farm layout planning--might assist with planning the overall layout and design of the project for farm units and, later, with some of the actual development work.

5.20 Another step, in order, is to select the farm families to assume responsibility for the individual farm units in the pilot area. If the area is established on GOT land, it is recommended that the new farm units be sold to carefully selected farm families who would be willing to assume reasonable debt obligations for long-term real estate loans for the small-farm units. They also should agree to follow their complete farm plans (with the improved technologies involved) which they assist in developing as explained below.

Individual Farm Planning

5.21 Each farmer in the study area will need to develop complete plans for his longrun farming system. This will be quite a departure from his cutomary "opportunity cropping" earlier described by Dr. Bolton in Chapter IV and he will need sustained personal assistance from the extension specialist assigned to the project. The specialist, in turn, may need consultant help from an agricultural economist, experienced in farm planning, for getting this work started.

5.21 In preparation for the planning work, the extension specialist will first need to solicit help from specialists in various subject-matter disciplines for updating gross-margin budgets for various crop and livestock enterprises to be considered by farmers in the area. Budget forms for this purpose were prepared in connection with the UMC Team Assignment in April 1978. Preliminary budgets for a number of crop and livestock enterprises are included in that report (pages 153 through 182) but should be revised in accordance with latest yield, price, and cost data available. Sample budgets are included in Appendix Section D of this report for dryland barley, sheep production, and other enterprises.

5.22 The next preparatory step is to assemble necessary forms (worksheets) to make economic evaluations of different (alternative) farming systems before one is chosen for development. A set of forms (Form TU-1 through TU-5) was designed for this purpose in April 1978 and a comparative example is included in the UMC April report (pages 184 to 193). An example set of forms is included in this report for an improved dryland system on a 30-ha. farm for Central Tunisia (Appendix Section E).

5.23 Using "tools" such as the above, the extension specialist and each individual farmer can conceptualize different kinds of crop and livestock combinations feasible for his farm and family resources and evaluate the economic potential for each before deciding on a plan to develop.

5.24 With the worksheets as a guide, the alternative plans can be developed and evaluated more effectively and quickly by following

a systematic and logical step-by-step procedure as outlined in the UMC April report (Appendix Section A, page 128).

Supervised Development of Plans

5.25 After all farmers in the project area have selected long-time plans to develop, cooperative efforts from several different individuals and groups will be needed and a number of different arrangements will need to be activated. Arrangements for these activities and developments will be the responsibility of the extension specialist assigned to the project. Aside from giving personal assistance to his cooperating farmers as problems arise, he can make necessary arrangements for activities and services such as outlined below.

5.26 Applied research. The farm units in the pilot study area provide an ideal setting for various kinds of applied research. Each new technology, or a "package" including several, may be studied as a part of an integrated farming system. The cumulative effect of coordinating several proven technologies in a complete farming system often far exceeds expectations. Furthermore, the extension specialist assigned is available to assist in establishing the research project and in getting the necessary records throughout the study.

5.27 Perhaps even more important in the long run is the opportunity to accumulate performance data, year-by-year, for the complete farm business units and the individual enterprises included. Each farm unit, which is unique in some ways, can become an individual farm management case study under supervision of the extension specialist. He will need to assume major responsibility for the necessary records

as many of the farmers may lack the educational background to do so.[1] These actual case-study records provide one source of information for improving and updating the budget data needed for future farm planning and subsequent evaluations.

5.28 Providing inputs and custom services. Implementation of plans by farmers in the project area will require various inputs--seeds, fertilizer, chemicals, custom services, etc.--on a timely schedule for effective development of the new farming systems. Help in acquiring these inputs and aiding in their proper use would be another function of the extension specialist for the project area.

5.29 Credit will be needed by most of the area farmers for acquiring inputs and services. If ineligible for credit from conventional sources, their needs might be met from a revolving loan fund, supplied by USAID or other sources as suggested elsewhere in this report. Preferably, such funds would be administered through existing credit channels with any necessary arrangements for expediting loan application processing and fund allocations.

5.30 Custom operators, well-trained and properly equipped, can serve a key role in developments within the project area. Perhaps a mechanically-inclined young man from the vicinity or an existing operator with some of the equipment already owned, could be provided financing for acquiring the additional machinery and equipment needed

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[1] William Litwiller, Agricultural Economist with the PASA team in Tunisia, has prepared a simplified recordbook for small farmers which might be adapted for use in the project area, along with any supplemental records needed for specific applied research projects.

for various kinds of work in the area. Such a set might include a tractor of adequate size; appropriate tillage tools; a drill with fertilizer attachments for cereal seeding; tools for applying herbicides and pesticides; a small blade and/or scoop for repairing terraces, dams, etc.; harvesting equipment; and other specialized tools needed for the kinds of farming systems developed.

5.31 Acceptance of the practice of hiring such custom services should be no problem as many farmers in the area (reported to be as high as 80% in some delegations) already hire custom operators, or neighboring farmers with tractor equipment, to do their limited tillage for cereal production. A smaller percent also hires equipment for combine harvesting of grain.

5.32 Custom rates for the various tasks would need to be set at a level equitable and reasonable for the farmer, but also high enough to cover the fixed and variable costs of owning and operating the equipment and a fair return for the operator's labor and management as well. Otherwise, he could not stay in business and continue to serve the area. It seems preferable for the custom operator to serve as a private entrepreneur rather than to work as an employed operator of equipment owned either by the GOT or a local cooperative.

5.33 Training of the custom operator and necessary follow-up supervision might be arranged by the Central Tunisia Office with the Le Kef farm machinery specialist and other staff members of the College. Initial training might include a special short course at Le Kef for intensive instruction in the operation and servicing of each new piece of equipment included in his set of tools. If the

custom operator already is a graduate of the two-year training program at Le Kef (someone with special aptitude for machinery operation and care), he could be especially helpful to the extension and applied research workers in implementing new interventions in a proper manner.

5.34 Peace Corps-Care/Medico assistance. The development of all the farm units within the pilot study area will require on-going supervision and assistance of a specific and detailed nature. Since the extension specialist may get quite involved with other responsibilities as well, it is suggested that USAID and the Central Tunisia Office explore with the Peace Corps and Care/Medico officials the possibility of assigning one or two volunteers to work with the extension specialist in each pilot study area.

5.35 In order to be of much value to the project, each volunteer assigned should have unique qualifications. Among them would be a farm background with actual experience in living and working on a family-size farm unit; an agricultural college degree with a major in such subjects as farm management, agronomy, or agricultural engineering; a sincere interest in the problems and welfare of farm families; a high degree of initiative and willingness to work directly with farm operators (sometimes at hard, physical labor); and the high moral character and other personal qualities required of all volunteers. It is presumed that the volunteer would receive the usual orientation and language training required of all volunteers.

5.36 Ideally, Peace Corps volunteers would work as a team with young Tunisians who also are interested in the same kind of work.

Perhaps selected students from the Le Kef training program could be employed on a part-time basis, during summer and vacation periods, to assist directly with the development work in the pilot areas. This on-the-job, apprentice-type experience would be excellent training for extension specialists to serve in other locations as the work expands in the Central Tunisia area.

5.37 Maintaining on-going records. Since the primary purpose of the pilot study areas is to establish patterns for new systems of farming involving many new technologies, good records of the total project are essential as a guide for future expansion.

5.38 In addition to the individual farm-unit records stressed in Paragraph 5.27, other records of the project development should be maintained, such as investments in land improvements and facilities, the time and cost of supervisory help, and the added employment and area income generated by the project.

Evaluation and Use of Demonstration Areas

5.39 Year-by-year records of performance are indispensable for future expansion within the project area. Kinds of records for individual farms and for the study area were suggested in Paragraphs 5.27 and 5.37. The extension specialist should have adequate filing facilities for keeping separate records for each farm unit and for overall data needed for the project.

5.40 The extension specialist, with any assistance needed from the extension training specialist from the Office and Le Kef, should take full advantage of the opportunity afforded for many types of method demonstrations as various phases of the project evolve. Such

activities as terrace construction, drilling seed and fertilizer for barley fields, applying herbicides and pesticides, planting almond trees with new systems of watering, etc., will naturally attract curiosity and interest among farmers over a wide area.

5.41 Arranging special field days, tours, meetings, etc., to explain what is being done and why, as well as demonstrating "how to do it," are good ways to create the interest needed for future expansion. Taking pictures for prints and colored slides to show the project before any work is started, and periodically as it progresses, should also be quite useful for reports, publicity, meetings, and other educational purposes.

Facilities and Personnel Needed

5.42 Proposed USAID financial assistance for the recommended interventions--including irrigation, dryland farming (cereal production), and erosion control and rainwater management--already have been summarized in Appendix Tables A-1, B-2 and C-5, C-6, C-7 and C-8. More detailed data relative to these proposed cost estimates are included in the respective narrative sections of the report and associated reference tables.

5.43 No additional USAID-supported personnel and facilities are proposed for the pilot study/demonstration areas suggested since they already have been included in those for the above specific interventions.

VI. ECONOMIC EVALUATIONS, CONDITIONS PRECEDENT TO IMPLEMENTATION, AND BUDGET ESTIMATES

6.1 One team assignment was to evaluate the economic consequences of the proposed interventions for individual farmers and for the area as a whole. Such micro- and macro-evaluations must be based upon best available benchmark data for the current performance of individual enterprises and farming systems in the area; upon sound projections of the future impact of the interventions proposed; upon workable procedures for analysis; upon the number of farm units to be affected in a given time period; and, upon any conditions precedent to successful implementation. Budget estimates for USAID interventions also are specified.

Bench Mark Data

6.2 Accurate information about the performance of individual enterprises and farming systems in the project area have not been accumulated from actual farm records over a period of years. Therefore, evaluations must be based upon surveys, field studies, and best estimates by knowledgeable persons. An effort was made to assemble such data for several individual crop and livestock enterprises during March of 1978 with the help of CNEA staff members and delegation officials. Such data are summarized in gross-margin budgets included in Appendix Section C of the April UMC report, pages 153 to 182.

6.3 Since some of the above data seemed out of date and numerous gaps seemed apparent in the data at hand, the CNEA staff assumed responsibility for conducting field surveys to update and supplement the information available before making the economic evaluations needed for the project. These surveys will be completed in late July and tentative arrangements are being made for one member of the UMC team, Dr. Itil Asmon, to return to Tunis the latter part of July to assist with these evaluations.

6.4 This new information is particularly essential for the irrigation interventions since they are expected to be implemented early in the project development period. The probable impact from the other proposed interventions is less urgent, and more difficult to assess, since implementation can only be carried out over a longer time period. However, some general estimates are included in earlier sections of this report.

Projection of Future Impacts

6.5 Improved yields and returns resulting from specific interventions also must be projected, based upon research data available and upon performance data on local farms where the new technologies already have been applied. Some information of this kind is expected to accrue from the current field surveys in the area.

Procedures for Analysis

6.6 For an economic evaluation of the impact of new technologies on individual farming systems, specific cost-return

data must be accumulated for individual drop and livestock enterprises included in the farming systems.

6.7 Gross-margin budgets for such enterprises provide useful "building blocks" with which to evaluate the farming systems--both "before" and "after" the new technologies are applied. They are essential for farm business analyses whether done with hand budgeting, linear programming, computer budgeting, or other more sophisticated techniques. Forms for preparing gross-margin budgets were prepared for several crop and livestock enterprises in connection with the first assignment and are included in Appendix Section C of the April UMC report. Sample budgets also are included for reference in Appendix Section D of this report. As new yield and price data, and future estimates, become available, these budgets can be updated rather quickly.

6.8 With best available enterprise budgets at hand, either a budgeting or programming procedure is needed for evaluating the economic consequences of new technologies when applied on individual farm units. A set of simplified budgeting procedures (Forms TU-1 through TU-5) were developed and included in Appendix Section D of the earlier UMC report. For illustrative purposes, a set of the forms completed for an improved system for a 30-hectare dryland farm in the project area, is included in Appendix Section E of this report.

6.9 By preparing a set of the analysis forms for a typical kind of farm in the area as presently operated and one or more sets for alternative systems with new technologies applied, economic

comparisons among the systems can be determined. As noted on Forms TU-4 and TU-5, such measures as net cash farm income, farm profits, return to family labor and management, return to capital, and net cash family income can be calculated for the various systems compared.

Estimating the Number of Farm Units Affected

6.10 The number of farm units in an area to be affected by a particular intervention must be estimated as accurately as possible in making macro-economic evaluations. For some interventions, such as the ones for shallow-and deep-well irrigation in this project, the number can be projected rather accurately. For others, such as erosion-control impacts which will accrue only over a period of many years, the task is much more difficult. Reliance upon the best judgment of those who work in the area and are most familiar with farming conditions and the farmers involved is about the only way to proceed.

Overall Conditions Precedent to Implementation

6.11 Both UMC consultant teams concur in three overall conditions which must be observed before any real progress can be made for agricultural improvement in the project area.

6.12 First of all, is the imperative need for action, to start implementing programs rather than waiting for a continuing series of follow-up studies. Numerous studies have been made over a period of

many years of the physical and institutional resources in the area (including studies of soil types, climatic conditions, groundwater aquifers, erosion losses, markets, roads, schools, etc.) and of the prevailing cultural and social conditions. While such information is interesting and useful, the crying need in the area is to start helping the small farmers make the necessary adjustments to improve their productivity, earnings, and living conditions.

6.13. A second urgent need in the area is for applied research conducted on farms within the eight delegations of the project area. The purpose of such studies is to determine what improved technologies and combinations of them in farming systems, really work under the unique resources and conditions which prevail and to evaluate their impact on the productivity and earnings from the small-farm units.

6.14 The third condition, associated with the above, is the imperative need for adequate scientific and technical personnel to conduct the applied research and to help assure proper implementation of the interventions recommended. In fact, without assurance of adequate staffing, the commitment of large investments of capital in the project area should be seriously questioned.

6.15 Since the interventions and technologies recommended represent radical departures from the traditional farming practices of local farmers, many of whom are not far removed from nomadic ways of life with little background for more intensive and complex farming systems, the need for personal assistance is obvious. But the alternative of exerting major efforts to convert the present cropland used for cereal production to rangeland pasture--

with the small, fragmented farm holdings, the numbers of people and forage-consuming animals in the area, and the soil and climatic conditions prevailing--would be doomed to failure from the start. Such shifts to more extensive land use, as sometimes proposed and desirable from the standpoint of good land use, would require massive movement of people out of the central area, a substantial reduction in forage-consuming animals (at least for a number of transition years), and farm units with far greater hectarages of land than presently exist.

6.17 In summary, adjustments needed in the project area are the kind made in many developed countries over a period of many decades. To expect such changes in Central Tunisia in a period of a few years, without substantial personnel, as well as physical and financial assistance, is quite unrealistic.

6.18 Scientific and technical workers to conduct applied research in all delegations of the project area is the first and most pressing need. Staffing needs for the Le Kef College unit (which seems essential for work in the project area) are outlined in detail in Section IV of this report and in Appendix Table C-1. Another asset of the Le Kef unit is the availability of students in the training school to assist with the details of the applied research. In the process, several young men would be getting practical on-the-job training which would be ideal preparation for future extension workers in the area.

6.19 It is also suggested that the Office and the Le Kef center explore the possibility of assigning one or two Peace Corps volunteers

to work with each mobile research unit in the project area. They might work in teams with students from the training school to aid in close supervision of the field trials established throughout the area.

6.20 The other imperative personnel need is for well-trained extension workers to live and work in the project area--in greater numbers than usually assigned and staffed with workers who are well-grounded in technical agriculture and who are interested in working closely with farmers in the actual application of new technologies.

6.21 A minimum extension staff in the area probably should be one well-trained extension specialist assigned to each of the eight delegations. Again, as the program develops, the effectiveness of his work might be multiplied by assigning one or more Tunisian assistants and perhaps a Peace Corps volunteer to work with him on detail work if such could be arranged. Such Peace Corps workers mentioned here and above should have the qualifications specified in Paragraph 5.33 of this report.

6.22 In addition to the delegation extension staff, each pilot study/demonstration area should be staffed with an extension farm-management type specialist, along with the assistants as described in Chapter V.

6.23 This proposed staffing for applied research and extension for the project area may seem exhorbitant but it seems doubtful if much real progress can be made in solving the complex problems of the area without it--regardless of the amount of investment capital committed.

Specific Conditions Precedent to Implementing Interventions

6.24 In order to give some assurance of success with a longrun rural development project envisioned in connection with these interventions, firm commitments will be necessary from USAID, the Government of Tunisia, any other participating agencies, and, most of all, from the small dryland farmers in the project area.

6.25 First of all, the participating groups and individuals must recognize the long-time nature of such a development project. The eroded soil, the depleted cropland, the overgrazed pastures, and the lack of systematic cropping programs and land use have evolved over a span of many generations. Hence, the idea that complete systems of farming can be revolutionized in such a disadvantaged area as Central Tunisia on a come-and-go basis--within a period of 3, 5, or 10 years--is futile and self-defeating.

6.26 However, the agricultural assessment team is convinced that substantial improvement in the productivity, farm income, and family living of the small farmers in the dryland areas can be achieved through a well-planned development program which is based upon sound information applicable to the area and which is implemented step-by-step in a logical and systematic manner over time. The imperative need is action, taking the necessary steps to start implementing the interventions known to be adapted, without further delay.

6.27 A few specific suggestions about actions different groups may take to help assure the longrun success of this development project are itemized below:

6.28 USAID actions. Some things AID staff may consider to make their contributions most effective are as follows:

1. Provide adequate financing for the interventions for which responsibility is assumed (for example, providing financing for half of the equipment for either a soil-testing laboratory or a mobile unit for field trials in the project area would be self-defeating);

2. Give primary attention and support to the participant training--the eventual accomplishments in the project area will correlate closely with the competence of the staff developed to serve the area;

3. Arrange for consultants--both long-term and short-term--who have had thorough training and first-hand experience in actually carrying out the improvements with which they are to assist; and

4. Maintain a strong agricultural component in the AID mission, including personnel specifically trained and experienced in agricultural production and farm management, in order to give personal direction to the agricultural consultants who assist with various phases of the development project, especially to those on short-term assignments.

6.29 Government of Tunisia actions. The GOT plays the key role in the Central Tunisia Development Project. Since it is a longrun effort to develop a major segment of the economy and of the citizens of the country, the eventual success will hinge largely upon the GOT policies and actions. Some suggestions are as follows:

1. Provide a structural arrangement which will expedite administration and implementation of the chosen interventions--one which can avoid delays and overlapping functions but also one which can make full use of the expertise available in the various institutes and subdivisions of the Ministry of Agriculture;

2. Assign individuals for participant training who are competent, who have adequate basic training in their respective disciplines, who are rural-minded with an agricultural background, who are willing to devote their professional careers to an agricultural development

project, and who have assignments to work in the Central Tunisia Project on their return;

3. Provide increasing employment opportunities--both within and outside the area--since the population pressure is too great on the available land resources to absorb growing numbers of employable young people, even with the rural development program envisioned in this project;

4. Arrange for adequate extension personnel to work directly and closely on a person-to-person basis with the small farmers in the project area and provide for adequate initial and periodic follow-up training for extension workers in the subject matter fields for which they are personally responsible;

5. Provide sufficient incentive to induce the trained personnel to live and work in the project area on a long-term basis--such things as salary increases, bonuses, provision of perquisites, etc., might be considered;

6. Take necessary actions to maintain a strong applied research and training center (such as started at Le Kef) to serve the Central Tunisia Project Area--it can provide a solid base for the longrun development program;

7. Lend strong support and take the lead in establishing well-located pilot study areas where complete farming systems can be established and evaluated year after year (these can be the show-window areas where the cumulative effect of combining many good farming practices can be demonstrated in a dramatic way and where applied research and extension workers can evaluate their recommendations in the most effective manner);

8. Study alternative pricing and marketing policies and facilities which will encourage and expedite orderly and equitable marketing for the increased output which should accrue from the improved farming systems; and

9. Arrange through the Central Tunisia Office for the Soil Conservation Service (under the leadership of director Hezim and his staff) to be directly involved in soil-erosion and dryland-rainwater management interventions--along with similar involvements of professional staff members of other institutes and divisions of the Ministry of Agriculture as the need arises.

Small Farmer Actions

6.30 Small farmers in the dryland areas--both individually and in neighborhood groups--must come to realize that the development program is designed for them but can succeed only with their active cooperation and personal efforts. They should understand that GOT and USAID assistance is provided only to help them get started with their own program to achieve more productive, profitable, and stable farming systems.

6.31 Some ways of bringing about this awareness are as follows:

1. Encourage farm leaders, in each locality where projects are undertaken, to become actively involved from the very beginning in planning and carrying out the necessary activities;

2. Keep local farmers completely informed about all programs in which they are to become personally involved;

3. Conduct local method and result demonstrations to show them how to apply new technologies and the results from their application; and

4. Provide supervision and on-the-farm-assistance in planning new farming systems and carrying out specific farming practices with which they are unfamiliar.

6.32 The greatest challenge to extension workers in the area is to motivate people to take action--to stimulate interest and create the desire for the improved farming practices they have observed. The above activities may help.

Budget Estimates for USAID Interventions

6.33 Estimates of USAID financial support needed for the major interventions are explained in detail in the respective sections of this report. Also, the proposed amounts are summarized and

calendarized through a three-year-period in Appendix Tables A-5, B-2, and C-5 through C-8.

VII. BIBLIOGRAPHY

The initial phase of a study of the agricultural potential of the Central Tunisia area was completed by a University of Missouri Assessment Team in April, 1978. This study included preparation of a rather detailed bibliography of pertinent reference publications, parts of which were provided by two members of the CNEA staff in Tunis, Mohamed Ech Chebeane and Monia Bouratbine. They also prepared a related publication which included an additional classified bibliography. These two references are as follows:

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VIII. APPENDIXES

Appendix Section	Title	Pages
A	Reference Data for Irrigation Interventions	108-115
B	Reference Data for Erosion Control and Rainwater Management	116-138
C	Reference Data for Cereal Crop (Barley-Wheat) Interventions in Dryland Areas	139-151
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APPENDIX SECTION A

Reference Data for Irrigation Intervention

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Appendix Table A-1: Main Aquifers in the Project Area

Delegation	Total sustained yield, 10^6 m^3/year		Present Utilization 10^6 m^3/year	Available Groundwater 10^6 m^3/year	Available Groundwater l/s of continuous flow
	Minimum Estimate	Maximum Estimate			
Foussana	7	14.5	3.5	3.5 to 11	110 to 350
Thala	n.d.[a]	n.d.	n.d.	n.d.	45 to ?
Djedliene Rohia	2	5	1	1 to 4	32 to 127
Maktar	G[b]	G	G	G	G
Sbiba	9.4	16.5	8.3	1.1 to 8.3	35 to 263
Sbeitla	11.5	17.5	9.5	1 to 4	32 to 127
Djilma	14	16	8	6 to 8	190 to 254

Minimal total available groundwater, l/s of continuous flow = 444

[a] n.d. = not determined

[b] G = insignificant

Sources: "Etude Hydrogeologique de la Plaine de Kalaa-Khasba", H. Zebidi, DRES, 1976; "Etude Hydrogeologique de la Plaine de Kalaa-Djerda", DRES; "Contribution á l'Etude Hydrogeologique de la Cuvette de la Foussana", H. Zebidi, DRES;; "Plan Directeur de l'Utilization des Eaux du Centre de la Tunisie-Dossier Analytique-Hydrogeoloque"-HYDRATEC/CEDRAT, Feb. 1977; CNEA; DRES.

The latter document contains maps of the above aquifers.

Appendix Table A-2: Improvements of Existing Shallow Wells

Delegation[a]	Foussana	Thala	Djedliene	Rohia	Djilma	Total
No. of Existing Shallow Wells	240	470	47	182	141	1,080
Shallow Wells Needing Small Improvements	20	150	--	--	30	200
Cost of Small Improvements, TD (at TD400 per well)	8,000	60,000	--	--	12,000	80,000
Shallow Wells to be Deepened and Lined	200	--	23	70	--	293
Cost of Deepening & Lining, TD (at TD 1500 per well)	300,000	--	34,500	105,000	--	439,500
Diesel Pumps to be Installed	40	--	14	--	30	84
Cost of Diesel Pumps, TD (at TD800 each)[b]	32,000	--	11,200	--	24,000	67,200
Electrical Pumps to Be Installed	100	--	9	36	--	145
Cost of Electrical Pumps, TD (at TD1250 each[c])	125,000	--	11,250	45,000	--	181,250
3000-volt Lines to Install km (at Herich)	4	--	--	--	--	4
Cost of Medium-tension Lines, TD (at TD3750/km) plus TD17,050 for Transformer	32,050	--	--	--	--	32,050
Total Investment in Existing Wells, TD		60,000	56,950	150,000	36,000	800,000

a/ The opportunities for improving shallow wells in Maktar, Sbiba and Sbeitla delegations are insignifcant.

b/ Including portable outlet pipe.

c/ Including portable outletpipe, instrument panel, low-tension line and a part of the transformer cost.

Sources: "Données Agro-Economiques de Base sur la Tunisie Centrale", CNEA, April 1978; "Projet de Développement Rural de la Tunisie Centrale", OMVVM-PPI, Feb. 1978; CNEA; local offices of the Central Tunisia Project and the Ministry of Agriculture; Mission observations.

Appendix Table A-3: New Shallow Wells to be Installed

Delegation[a]	Foussana	Thala	Djedliene	Rohia	Djilma	Total
New Wells to be Installed	50	45	70	40	20	225
Cost to Owner:						
Excavation, TD (at TD 300 each)	15,000	13,500	21,000	12,000	6,000	67,500
Cost to Project:						
Cost of Lining, TD (at TD 1500 each)	75,000	67,500	105,000	60,000	30,000	337,500
Cost of Diesel Pumps, TD (at TD 800 each)	40,000	--	24,000[b]	--	16,000	80,000
Cost of Electrical Pumps, TD (at TD 1250 each)	--	56,250	50,000[c]	50,000	--	156,250
3000-Volt Line to Install, KM (at Hmeima)	--	--	4	--	--	4
Cost of Medium-tension Line (at TD3750/Km, plus TD 17,000 for transformer)	--	--	32,000	--	--	32,000
Total Project Investment in New Wells, TD	115,000	123,750	211,000	110,000	46,000	605,750
Total Project Investment in Existing and New Wells, TD	612,000	183,750	267,950	260,000	82,000	1,405,700

a/ The opportunities for new wells in Maktar, Sbiba and Sbeitla are insignificant.

b/ For 30 wells (in the Terbah sector)

c/ For 40 wells (10 in the Oued Kerib and 30 in the Hmeima sectors)

Sources: as cited for Tables A-1 and A-2.

Appendix Table A-4: Schedule for Implementing the Proposed Activities

	1979	1980	1981	Project Total
A. Improvement of existing shallow wells				
1. No. of wells with small improvements	50	75	75	200
2. No. of wells to be deepened & lined	93	100	100	293
3. No. of diesel pumps to be installed	24	30	30	84
4. No. of electrical pumps to be installed	35	55	55	145
5. No. of km of 3000-volt line	--	4	--	4
B. Installing new shallow wells				
1. No. of wells to be installed	50	75	100	225
2. No. of diesel pumps	25	35	40	100
3. No. of electrical pumps	25	40	60	125
4. No. of km of 3000-volt line	--	--	4	4
C. Improvement of natural springs				
1. No. of springs to be improved	33	33	33	99
D. Developing perimeters of unused deep wells				
1. 4 deep wells in Foussana (ha developed)	70	70	70	210
2. Ein Hdia perimeter (ha developed)	100	--	--	100
E. Improvement of functioning perimeters				
1. Sbiba (levelling - ha)	--	500	500	1000
2. Hadjeb 7 and 8, Sabbalet (levelling and canals - ha)	--	190	190	380

Table A-5: Schedule of Investments (in Dinars)

	1979	1980	1981	Project Total
A. Improvements of existing shallow wells:				
1. Small improvements (TD 400/well)	20,000	30,000	30,000	80,000
2. Deepening and lining (TD 1500/well)	139,500	150,000	150,000	439,500
3. Diesel pumps (TD 800 each)	19,200	24,000	24,000	67,200
4. Electrical pumps (TD 1250 each)	43,750	68,750	68,750	181,250
5. 3000-volt line	--	32,050	--	32,050
Sub-total for improvement of shallow wells	222,450	304,800	272,750	800,000
B. Installing new shallow wells:				
1. Lining (TD 1500/well)	75,000	112,500	150,000	337,500
2. Diesel pumps (TD 800 each)	20,000	28,000	32,000	80,000
3. Electrical pumps (TD 1250 each)	31,250	50,000	75,000	156,250
4. 3000-volt line	--	--	32,000	32,000
Sub-total, installing new shallow wells	126,250	190,500	289,000	605,750
C. Improvements of Natural springs:				
1. Spring improvements (TD 750 each)	24,750	24,750	24,750	74,250
Total, Shallow Wells and Springs	373,450	520,050	586,500	1,480,000
D. Developing perimeters of capped deep wells:				
1. 4 deep wells at Foussana (TD 1900/ha)	133,000	133,000	134,000	400,000
2. Ein Hdia perimeter (TD 1000/ha)	100,000	--	--	100,000
Sub-total, perimeters of capped wells	233,000	133,000	134,000	500,000
E. Improvement of functioning perimeters:				
1. Sbiba-levelling (TD 120/ha)	--	60,000	60,000	120,000
2. Hadjeb 7 & 8, Sabbalet (TD 290/ha)	--	55,000	55,000	110,000
Sub-total, improvement of functioning perimeters	--	115,000	115,000	230,000
Total, deep-well perimeters	233,000	248,000	249,000	730,000
Grand Total, irrigation investments	606,450	768,050	835,500	2,210,000

High Priority: A, B, & C; Intermediate Priority: D; Low Priority: E

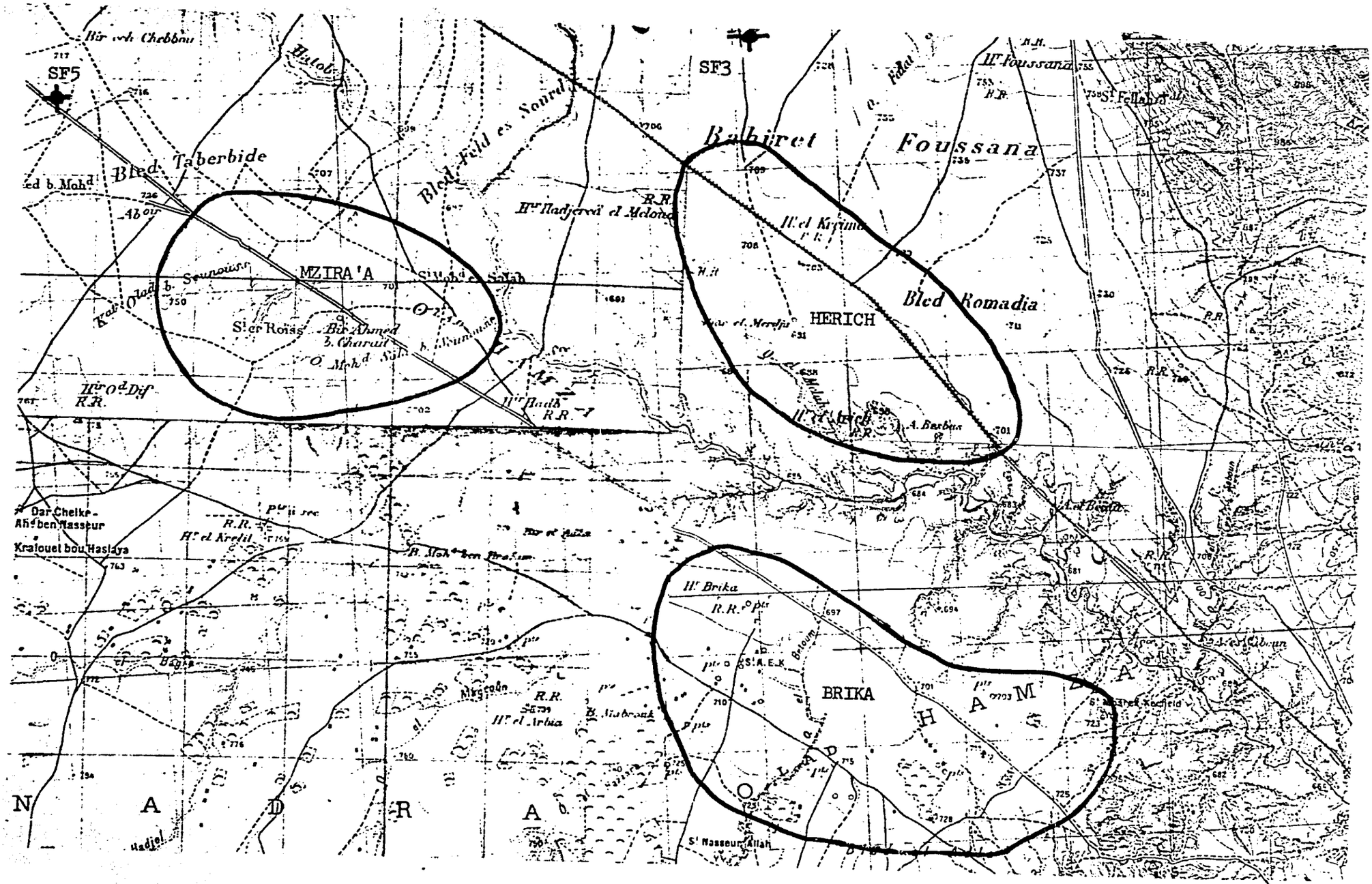


Figure A-1: The Brika, Mzira'a and Herich Shallow-well Concentrations
(Foussana Delegation)

Scale 1: 50.000

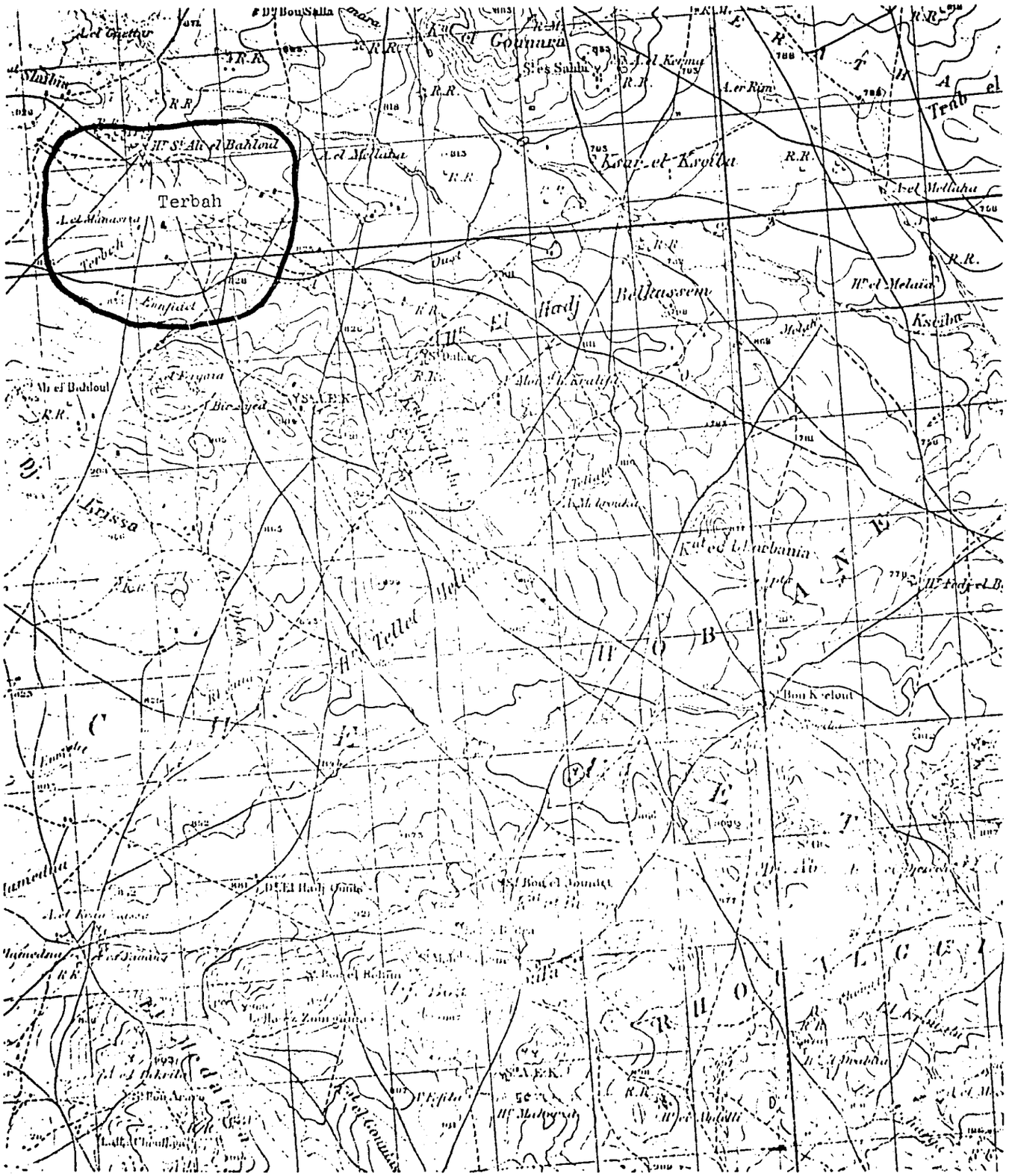
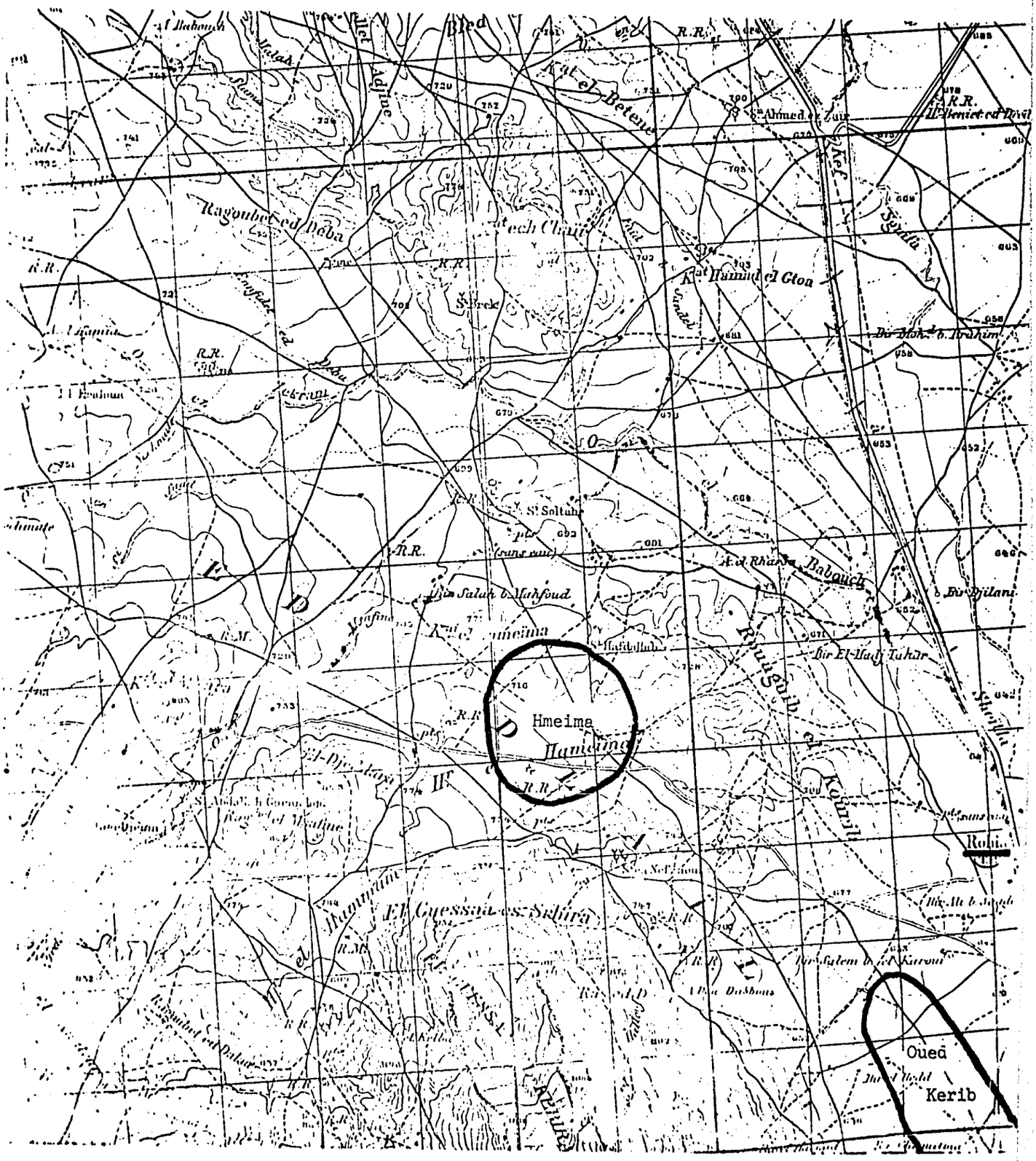


Figure 1.2: The Oued Derib, Kheira and Terbah Shallow-Well Concentrations (Djedliene Delegation)

Scale 1:50,000


Hmeima
Oued
Kerib

APPENDIX SECTION B

Reference Data for Erosion Control and Rainwater Management

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Appendix Table B-1. Rainfall Data for the Central Tunisia Project Area.

Stations	Average Rainfall (mm)	Fall Rainfall (mm)	Spring Rainfall (mm)	Amount of Rainfall Received At Least 9 Yrs. out of 10
Kasserine Chambi	360	100	80	200
Foussana	300	110	120	200
Thala	400	120	140	300
Sbiba	350	98	100	200
Rohia	350	100	100	200
Sbeitla	310	100	90	180
Djilma	268	85	90	180

Source: CNEA, Tunisia

Appendix Table B-2: Cost Estimates for Proposed Erosion Control and Water Conservation Pilot Program Intervention

Item	Amount by Years											
	1979			1980			1981			3-Year Total		
	MM	$	TD	MM	$	TD	MM	$	TD	MM	$	TD
Participant training in U.S. (1979-80) M.S. in Agricultural Engineering, Soil Conservation Emphasis	24	28,800	-	24	28,800	-	-	-	-	(Technology Transfer)		
Short-term Participant Training, Non-academic 2 participants each year; 3 years	6	12,600	5,250	6	14,100	5,875	6	15,090	6,287	18	41,790	17,412
AID Consultants												
Soil Conservation Eng.	4	44,000	18,333	6	66,000	27,500	2	22,000	9,167	12	132,000	55,000
Farm Management Econ.	3	33,000	13,750	3	33,000	13,750	6	66,000	27,500	12	132,000	55,000
Equipment Rental for Const.		-	-		120,000	50,000		60,000	25,000		180,000	75,000
Miscellaneous Supplies		12,000	5,000		12,000	5,000		12,000	5,000		36,000	15,000
TOTALS		101,600	42,333		245,100	102,125		175,090	72,954		521,790	217,412

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Design Criteria for Terraces

R. P. Beasley, Department of Agricultural Engineering, College of Agriculture

Terrace design considerations include spacing, channel grade, cross section and length.

Terrace Spacing

Spacing of Graded or Level Terraces: The equation VI = 0.6S + Y should be used to space terraces, unless otherwise specified. In this equation:

VI = Vertical interval between terraces, feet.

S = The average slope of the land draining into the terrace, percent.

Y = A variable depending upon the erodibility of the soil and the irregularity of the slope. Use Y = 1.3 if the field to be terraced has erodible soils and the slopes are such that there will be excessive concentration of runoff between terraces.

Use Y = 2.0 if the field has less erodible soils and the slopes are such that there will not be excessive concentration of runoff between terraces.

The spacings in Table 1 are computed by these equations. Use these spacings if there is to be no attempt to improve alignment of terraces. These spacings may be varied by 10 percent to miss obstacles in the field, to adjust for use of farm machinery, or to reach a satisfactory outlet.

The drainage area above a terrace should not exceed the area that would be drained by a terrace of equal length with normal spacing. When the area between the ridge top and the top terrace exceeds this area and is in other ownership, farmstead, permanent grassland or woodland areas, the top terrace should be replaced by a diversion and normal spacing used on the other terraces.

Spacing, Graded or Level Terraces for Improved Alignment: If terraces, or sections of terraces, are to be parallel then make some adjustment of spacings in Table 1 to accommodate the width of machinery that will most likely be used in farming the terraces.

TABLE 1

SPACINGS FOR GRADED OR LEVEL TERRACES

Average Slope of Area Draining Into Terrace, %.	Less Erodible Soils,* Uniform Slopes		More Erodible Soils, Irregular Slopes	
	Vertical Interval, Feet	Horizontal Distance, Feet	Vertical Interval, Feet	Horizontal Distance, Feet
1**	2.6	260	1.9	190
2	3.2	160	2.5	125
3	3.8	127	3.1	103
4	4.4	110	3.7	93
5	5.0	100	4.3	86
6	5.6	93	4.9	82
7	6.2	89	5.5	79
8	6.8	85	6.1	76
9	7.4	82	6.7	74
10	8.0	80	7.3	73
11	8.6	78	7.9	72
12	9.2	77	8.5	71

*Less erodible soils, in general, include those soils with a soil erodibility value "K" less than 0.38. Marshall, Sharpsburg, Summit, Bates and Newtonia are soils typical of this group.

More erodible soils, in general, include those soils with a soil erodibility value "K" greater than 0.42. Adair, Lamoni, Clarinda and Keswick are soils typical of this group. This spacing should also be used in the southeastern section of the state where intense rains can be expected in the winter and spring when there is little vegetative cover to give protection. Loring, Memphis and Grenada would be typical soils in this area.

The spacing to be used for soils with a soil erodibility value "K" between 0.38 and 0.42 will depend on the slope in the field. If the slopes are such that there will be excessive concentration of runoff between terraces, use the closer spacing.

**For slopes less than 2 percent, consider using cross-slope channels, see UMC Guide 1507, "Design Criteria for Cross-Slope Channels."

Use Table 2 to determine terrace spacing to best fit a majority of equipment widths. If the specific size of equipment and row spacing that will be used is known, refer to Table 3.

TABLE 2

SUGGESTED SPACINGS FOR PARALLEL SECTIONS OF GRADED OR LEVEL TERRACES*

Average Slope of Area Draining Into Terrace, %.	Less Erodible Soils, Uniform Slopes, Vertical Interval, Feet	Horizontal Distance, Feet	More Erodible Soils, Irregular Slopes Vertical Interval, Feet	Horizontal Distance, Feet
1	2.4	240	2.0	200
2	3.2	160	2.4	120
3	3.6	120	3.2	107
4	4.8	120	3.8	94
5	5.3	107	4.7	94
6	5.6	94	4.8	80
7	6.6	94	5.6	80
8	7.5	94	6.4	80
9	7.2	80	7.2	80
10	8.0	80	8.0	80
11	8.8	80	7.4	67
12	9.6	80	8.0	67
Over 12		80		67

* Spacings that best fit a majority of equipment widths.

Channel Grades

Level Terraces: Level terraces may be constructed on deep, permeable soils that are capable of absorbing and storing the runoff without appreciable crop damage, and without serious delay in the farming operations. The more permeable and deeper loess soils are the most suitable for level terraces.

Graded Terraces: The most desirable channel grade will vary with the soil type. It is difficult to construct the terrace to an exact grade, and tillage operations will cause obstructions in the channel. Give sufficient grade so ponding in the channel will not seriously damage crops or delay field operations.

If the terrace is constructed with a channel grade steeper than desirable, the increased velocity of flow will cause a higher rate of runoff. Excessive channel grade will result in channel erosion and silt buildup in the terrace outlet.

The most desirable grades to be used under most conditions are given in Table 4.

TABLE 4

DESIRABLE GRADES FOR TERRACES

Soil Permeability	Desirable Grade, Percent
Low	0.4*
High	0.3

* For terraces over 1200 feet long observe maximum grade given in Table 6.

In order to improve alignment of terraces it is permissible to vary from the most desirable grade. The grade in a section of a terrace may be varied as long as it is between the minimum and maximum grades specified for that section.

Suggested minimum grades are in Table 5. Maximum permissible grades are in Table 6.

TABLE 5

MINIMUM GRADES FOR TERRACES

Soil Permeability	Minimum Grade, Percent
Low	0.2
High	0.0

TABLE 6

MAXIMUM GRADES TO BE USED IN A TERRACE

Distance from Upper End of Terrace,* Feet.	Maximum Grade, Percent **	Maximum Drop in a 50-foot Interval
0 to 50	2.4	1.2
50 to 100	2.0	1.0
100 to 150	1.6	0.8
150 to 200	1.2	0.6
200 to 250	1.0	0.5
250 to 300	0.8	0.4
300 to 350	0.7	0.35
350 to 450	0.6	0.3
450 to 550	0.5	0.25
550 to 1200	0.4	0.2
1200 to 1600	0.3	0.15

* Assuming a drainage area equivalent to a normal terrace spacing for this length.

** If the terrace discharges into a grass outlet, the grade in the 50-foot section next to the outlet should not exceed 0.4 percent or 0.3 percent if the length of the terrace exceeds 1200 feet.

TABLE 3

TERRACE SPACING NEEDED FOR SPECIFIC SIZES OF EQUIPMENT

Number of Rows	4		6		4		8		6			6		8	
Row Width	30"		20"		40"		20"		30"			40"		30"	
Equipment Width	10'				13 1/3				15'			20'			
	Trips		Spacing, Feet		Trips		Spacing, Feet		Trips		Spacing, Feet	Trips		Spacing, Feet	
	6	--	60		5	--	67		4	--	60	3	--	60	
	8	--	80		6	--	80		5	--	75	4	--	80	
	9	--	90		7	--	94		6	--	90	5	--	100	
	11	--	110		8	--	107		7	--	105	6	--	120	
	12	--	120		9	--	120		8	--	120	7	--	140	
	14	--	140		10	--	133		9	--	135	8	--	160	
	16	--	160		12	--	160		11	--	165	9	--	180	
	18	--	180		14	--	188		12	--	180	10	--	200	
	20	--	200		15	--	200		13	--	195	12	--	240	
	24	--	240		18	--	240		16	--	240				

Terrace Cross Section

A terrace cross section should have adequate capacity for the runoff; be designed to fit the topography, the farm machinery to be used and the crops grown; and be economical to construct with equipment available.

Cross Section for Graded Terraces: Graded terraces should have the capacity to carry the peak rate of runoff to be expected in a 10-year period. A typical broad-base terrace cross section with a V-shaped channel is shown in Fig. 1. A terrace may also be constructed with a flat bottom as indicated by the dotted line in Fig. 1 if past experience on certain soils and slopes indicates that the flat bottom channel is easier to construct and to farm. The minimum constructed height of the terrace ridge is given in Table 7. If the fill is not compacted thoroughly during construction, provide additional height to allow for settling.

The shape of the terrace cross section should be designed to best fit the machinery to be used in farming the terrace.

TABLE 7

MINIMUM CONSTRUCTED RIDGE HEIGHTS FOR TERRACES (MEASURED AS INDICATED BY (h) IN FIGURE 1)

Distance From Upper End of Terrace, * Feet	Minimum Constructed Ridge Height, feet. **		
	Graded Terraces		Level Terraces All Slopes
	Land Slope Over 8%	Land Slope 0 to 8%	
0 to 400	1.2	1.0	1.5
400 to 600	1.2	1.1	1.5
600 to 800	1.3	1.2	1.5
800 to 1000	1.4	1.3	1.5
1000 to 1300	1.5	1.4	1.5
1300 to 1600	1.5	1.5	1.5

* Assuming a drainage area equivalent to a normal terrace spacing for this length.

** Height is measured from a point 1½ feet from the peak of the ridge to a point 1½ feet from the center of a V-shaped channel or to the bottom of a flat channel.

This may vary from the typical shape shown in Fig. 1. On soils with a shallow topsoil underlain by unproductive subsoil a minimum amount of topsoil should be disturbed in constructing the terrace. If equipment less than 14 feet in width is to be used in farming these terraces, the cut slope may be made less than is indicated in Fig. 1. However, in no case shall the capacity of the terrace be less than indicated by Fig. 1 and Table 7.

Depth of cut in the terrace channel may be varied to reduce the curvature and improve the alignment of terraces.

Cross Section for Level Terraces: The cross section should be the same as for graded terraces except that the channel in all cases must have sufficient capacity to store at least 2 inches of runoff from the area draining into the terrace. The minimum constructed ridge height to give this capacity is 1.5 feet, as indicated in Table 7.

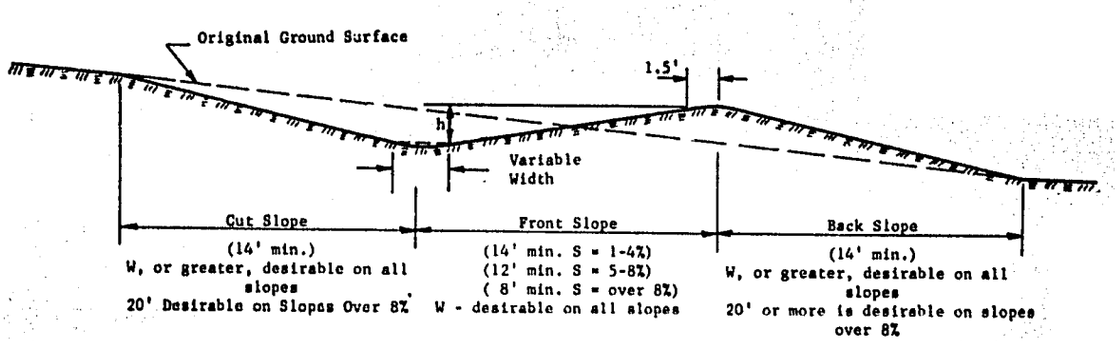
Partially close the ends of level terraces with a channel block at least 0.7 foot above the channel. Construct similar blocks as needed to distribute the water throughout the channel. Channel blocks should have side slopes no steeper than 6 to 1 and a minimum top width of 6 feet.

Terrace Length

Generally, terraces should not exceed 1,600 feet in length. When a greater length is used, that portion of the terrace greater than 1,600 feet in length should be designed as a diversion.

Terrace Outlets

All terraces must have adequate outlets. Outlets may consist of a vegetated area, a constructed and vegetated channel, or other stable outlet. The outlet must convey runoff from the terraces to a point where the outflow will not cause damage. It is desirable to establish vegetated outlets in advance of terrace construction to insure adequate vegetative cover.



W = the maximum width of machinery to be used to farm the terrace.
S = the slope of the original ground surface.
h = the height of the terrace ridge - measured as indicated, minimum values of h are given in Table 7.

Figure 1. A typical terrace cross section.

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Design Criteria for Diversions

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Diversions are used to divert water from areas where it is in excess to locations where it can be disposed of safely. They may be used to:

1. Protect cropland, pasture land, farmsteads, or other improvements from runoff.
2. Intercept shallow subsurface flow which is causing wet areas.
3. Divert runoff from terrace outlets and water impounding structures to where it can be disposed of safely.
4. Provide additional runoff for water storage structures.

Diversions are not a substitute for terraces on land requiring terracing for erosion control.

Designing Diversions

Considerations in designing diversions include capacity, permissible velocity, channel grade, and cross section.

Capacity: A diversion must have the capacity to provide the degree of protection desired. The minimum capacity should not be less than that required to carry a 10-year frequency runoff. A larger channel that will overflow less frequently can be constructed if the damage from more frequent overflow is greater than the additional cost of construction. Obtain peak rates of runoff from UMC Guide 1518, "Estimating Peak Rates of Runoff From Small Watersheds."

Maximum Permissible Velocity: Select a velocity which will result in a channel that can be constructed at a minimum cost and which can be easily maintained. A higher selected velocity will result in a smaller channel to carry a given flow; however, the velocity should not be high enough to erode the channel. Consider the erodibility of the soil to be exposed in the channel of the diversion and the type and quality of vegetation that can be established and maintained when selecting the maximum permissible velocity. Use Table 1 in selecting the maximum permissible velocity and Table 3 in determining the size of channel if:

1. The runoff can be diverted from the channel while vegetation is established,
2. Soil conditions are favorable for establishment of a dense stand of grass, and
3. Good management practices will be followed in establishing and maintaining the grass.
4. The diversion is constructed in rocky soil that is very resistant to erosion.

Use Table 2 in selecting the maximum permissible velocity and Table 4 in determining the size of channel if:

1. Runoff can't be diverted from the channel,
2. Soil conditions are not favorable for establishing dense grass, and
3. Good management practices are not likely to be followed.

TABLE 1

MAXIMUM PERMISSIBLE VELOCITIES
Feet Per Second

(To be used if a stand of erosion resistant grasses can be established and maintained in the channel)

Vegetative Cover	Less Erodible Soils*	More Erodible Soils**
Fair	4.0	3.5
Good	5.0	4.0
Excellent	6.0	5.0

* Less erodible soils are generally those with a higher clay content and higher plasticity. Typical soil textures are silty clay, sandy clay and clay.

** More erodible soils are generally those that have a high content of fine sand or silt and lower plasticity. Typical soil textures are fine sand, silt, sandy loam and silty loam.

TABLE 2

MAXIMUM PERMISSIBLE VELOCITIES
Feet Per Second

(To be used if a stand of grass cannot be established and maintained)

Vegetative Cover	Less Erodible Soils*	More Erodible Soils**
None - Cultivated	2.0	1.5
None - Not Cultivated	2.5	2.0
Sparse Annual Grasses	3.0	2.5
Fair Annual Grasses	3.5	3.0

* Less erodible soils are generally those with a higher clay content and higher plasticity. Typical soil textures are silty clay, sandy clay and clay.

** More erodible soils are generally those that have a high content of fine sand or silt and lower plasticity. Typical soil textures are fine sand, silt, sandy loam and silty loam.

This Guide prepared jointly by state and field staffs of the College of Agriculture, University of Missouri-Columbia, and the Soil Conservation Service.

Channel Grade: The topography at the site where the diversion is to be built will in some cases determine the channel grade. It may be necessary to shift the diversion from the most desirable location in order to obtain a grade which will result in the desired velocity.

If the channel grade does not exceed 0.8 percent use Tables 3 and 4 to select the size of channel. If the grade in the channel exceeds 0.8 percent it will be necessary to establish and maintain a good stand of erosion resistance grasses in the channel. Use the tables for designing grass waterways to select the channel width and depth for grades in excess of 0.8 percent. See UMC Guide 1505, "Design Criteria for Grass Waterways." Sufficient depth for freeboard is also included in these tables.

Cross Section: A diversion should have a trapezoidal-shaped cross section with a flat bottom and 4 to 1 side slopes where possible. See Fig. 1. Determine the bottom width of the channel and the height of the ridge required to carry a given rate of runoff at or below the maximum permissible velocity from Tables 3 or 4.

In most cases a number of channels with different bottom widths and heights will carry the given flow at or below the maximum permissible velocity. The size selected will depend on the land slope on which the diversion is to be constructed, the type of equipment available for construction, the cost, the location of the channel, and maintenance requirements.

If the diversion is constructed on steep land or where space is limited it may be desirable to construct the channel with 3 to 1 side slopes. If this is done the maximum rate of runoff should be increased by 10 percent and Tables 3 or 4 used to select the bottom width and height of channel.

The heights of ridge given in Tables 3 and 4 are based on a well compacted fill. Measure the height from the bottom of the channel to a point 2 feet off the peak of the ridge, H in Fig. 1.

Outlet

Each diversion must have an adequate outlet. The outlet may be a constructed and vegetated channel, a stable watercourse, a grade stabilization structure or other stable outlet.

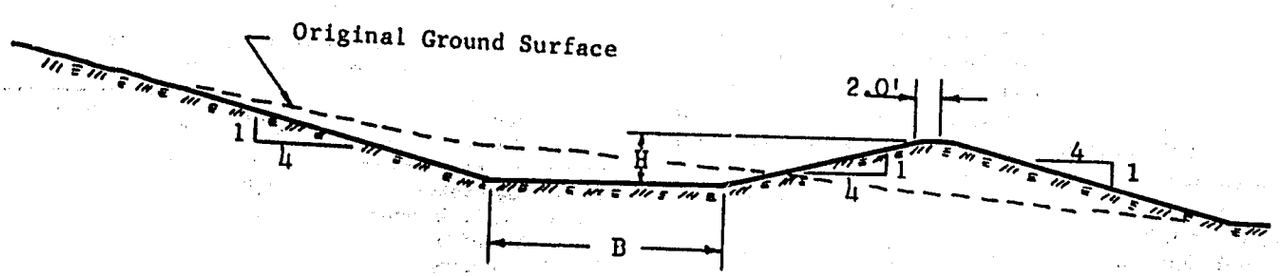

Figure 1. Cross section of a diversion

TABLE 3

HEIGHTS (H)* OF DIVERSION RIDGE WITH GRASS ESTABLISHED AND MAINTAINED IN CHANNEL

Q, cfs	Bottom Width (B)** feet	6				8				10				Q, cfs
	Grade, percent	0.2	0.4	0.6	0.8	0.2	0.4	0.6	0.8	0.2	0.4	0.6	0.8	
5			1.6	1.4	1.2		1.5	1.3	1.2		1.4	1.2	1.1	5
10			1.8	1.6	1.3	1.2	1.7	1.5	1.3	1.1	1.6	1.4	1.2	10
15		1.0	2.0	1.7	1.5	1.4	1.8	1.6	1.4	1.2	1.7	1.5	1.3	15
20			2.1	1.8	1.6	1.5	1.9	1.7	1.5	1.4	1.8	1.6	1.4	20
25			2.2	1.9	1.7	1.6	2.0	1.8	1.6	1.5	1.9	1.7	1.5	25
30		1.5	2.3	2.0	1.7	1.6	2.1	1.8	1.6	1.5	2.0	1.7	1.5	30
35			2.4	2.1	1.8	1.7	2.2	1.9	1.7	1.6	2.0	1.8	1.6	35
40			2.5	2.1	1.9	1.8	2.3	1.9	1.8	1.7	2.1	1.8	1.7	40
45			2.6	2.2	2.0	1.8	2.4	2.0	1.9	1.7	2.2	1.9	1.8	45
50			2.6	2.3	2.0	1.9	2.4	2.1	1.9	1.8	2.3	2.0	1.8	50
60		2.0	2.7	2.4	2.1	2.0	2.5	2.2	2.0	1.9	2.4	2.1	1.9	60
70			2.8	2.5	2.2	2.0	2.6	2.3	2.1	1.9	2.5	2.2	2.0	70
80			2.9	2.6	2.3	2.1	2.7	2.4	2.2	2.0	2.6	2.3	2.1	80
90		2.5	3.0	2.7	2.4	2.2	2.8	2.5	2.3	2.1	2.7	2.4	2.1	90
100		3.0		2.8	2.6	2.3	2.9	2.6	2.3	2.2	2.8	2.5	2.2	100
120				2.9	2.7	2.5	3.0	2.7	2.4	2.3	2.9	2.6	2.3	120
140				3.0	2.8	2.6		2.8	2.6	2.4	3.0	2.7	2.4	140
160			4.0		2.9	2.7	3.0	2.9	2.7	2.5		2.8	2.6	160
180					3.0			3.0	2.8	2.6	4.0	2.9	2.7	180
200				5.0			4.0		2.9			3.0	2.8	200
220								5.0	3.0		5.0		2.9	220
240													3.0	240

TABLE 3 - (continued)

Q, cfs	Bottom Width (B)** feet	12				16				20				Q, cfs
	Grade, percent	0.2	0.4	0.6	0.8	0.2	0.4	0.6	0.8	0.2	0.4	0.6	0.8	
5			1.4	1.2	1.1		1.3	1.2			1.3	1.2		5
10			1.6	1.4	1.2	1.1	1.5	1.3	1.2	1.1	1.4	1.2	1.1	10
15		1.0	1.7	1.5	1.3	1.2	1.6	1.4	1.3	1.2	1.5	1.3	1.2	15
20			1.7	1.5	1.3	1.2	1.6	1.4	1.3	1.2	1.5	1.3	1.2	20
25			1.8	1.6	1.4	1.3	1.7	1.5	1.4	1.3	1.6	1.4	1.3	25
30			1.9	1.6	1.5	1.4	1.8	1.5	1.4	1.3	1.6	1.5	1.3	30
35			1.9	1.7	1.5	1.4	1.8	1.6	1.5	1.3	1.7	1.5	1.4	35
40		1.5	2.0	1.7	1.6	1.5	1.9	1.6	1.5	1.4	1.8	1.6	1.4	40
45			2.1	1.8	1.7	1.5	2.0	1.7	1.6	1.4	1.9	1.6	1.5	45
50			2.2	1.9	1.7	1.6	2.0	1.8	1.6	1.5	1.9	1.7	1.5	50
60			2.3	2.0	1.8	1.7	2.1	1.8	1.7	1.6	2.0	1.7	1.6	60
70		2.0	2.4	2.0	1.9	1.7	2.2	1.9	1.8	1.6	2.1	1.8	1.6	70
80			2.5	2.1	2.0	1.8	2.3	2.0	1.9	1.7	2.1	1.9	1.7	80
90			2.6	2.2	2.0	1.9	2.4	2.1	1.9	1.8	2.2	1.9	1.8	90
100			2.7	2.3	2.1	2.0	2.5	2.2	2.0	1.9	2.3	2.0	1.8	100
120		2.5	2.8	2.4	2.2	2.1	2.6	2.3	2.1	2.0	2.5	2.1	1.9	120
140			3.0	2.6	2.3	2.2	2.8	2.4	2.2	2.1	2.6	2.3	2.0	140
160				2.7	2.4	2.3	2.9	2.5	2.3	2.2	2.7	2.4	2.1	160
180				2.8	2.5	2.4	3.0	2.6	2.4	2.3	2.9	2.5	2.2	180
200			3.0	2.9	2.6			2.7	2.5	2.4	3.0	2.6	2.3	200
220				3.0	2.7		3.0		2.6			2.7	2.4	220
240					2.8			2.8	2.7		3.0	2.8	2.5	240
260			4.0		2.9		4.0	2.9	2.8			2.9	2.6	260
280								3.0			4.0	3.0	2.6	280
300				5.0			5.0						2.7	300
											5.0			

* Height, feet, required to carry flow with long grass in channel ("C" retardance), including 0.3-foot freeboard, measured from the bottom of the channel to a point 2 feet off the peak of the ridge.

** Bottom Width required to give desired velocity with short grass in channel ("D" retardance).

◯ Velocity, in feet per second, to be expected in channel with short grass ("D" retardance).

TABLE 4
HEIGHTS (H)* OF DIVERSION RIDGE WITH SPARSE VEGETATION IN CHANNEL

Q, cfs	Bottom Width (B)** feet	6				8				10				Q, cfs
	Grade, percent	0.2	0.4	0.6	0.8	0.2	0.4	0.6	0.8	0.2	0.4	0.6	0.8	
5		(1.0) 1.3	1.1	1.0	1.0	(1.0) 1.2	1.0	1.0	1.0	(1.0) 1.1	1.0	1.0	1.0	5
10		1.5	1.3	1.1	1.1	1.3	1.2	1.1	1.0	1.3	1.1	1.0	1.0	10
15		1.7	1.4	1.3	1.2	1.5	1.3	1.2	1.0	1.4	1.2	1.1	1.0	15
20		(1.5) 1.8	1.5	1.4	1.3	(1.5) 1.6	1.4	1.3	1.1	(1.5) 1.5	1.3	1.2	1.1	20
25		1.9	1.6	1.5	1.4	1.7	1.5	1.4	1.2	1.6	1.4	1.2	1.2	25
30		(2.0) 2.0	1.6	1.5	1.5	(2.0) 1.8	1.6	1.5	1.3	1.7	1.5	1.3	1.3	30
35		2.1	1.7	1.6		1.9	1.7	1.5	1.4	(2.0) 1.8	1.6	1.3	1.3	35
40		2.2	1.8	1.7		2.0	1.7	1.6		1.9	1.6	1.4		40
45		2.3	1.9			2.1	1.8			2.0	1.7	1.5		45
50		(2.5) 2.3	2.0			(2.5) 2.2	1.9			2.1	1.8			50
60		2.4				2.3	2.0			(2.5) 2.2	1.9			60
70		2.5				2.4				2.3				70
80		2.7				2.5				2.4				80
90		(3.0) 2.8				(3.0) 2.5				2.5				90
100		2.9				2.6				(3.0) 2.6				100
120		3.1				2.8				2.7				120
140		(3.5) 3.3				(3.5) 3.0				(3.5) 2.8				140

TABLE 4 - (continued)

Q, cfs	Bottom Width (B)** feet	12				16				20				Q, cfs
	Grade, percent	0.2	0.4	0.6	0.8	0.2	0.4	0.6	0.8	0.2	0.4	0.6	0.8	
5		(1.0) 1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	5
10		1.3	1.1	1.0	1.0	(1.0) 1.2	1.0	1.0	1.0	(1.0) 1.1	1.0	1.0	1.0	10
15		1.4	1.2	1.0	1.0	1.3	1.1	1.0	1.0	1.2	1.1	1.0	1.0	15
20		1.5	1.3	1.1	1.0	1.4	1.2	1.1	1.0	1.3	1.1	1.0	1.0	20
25		(1.5) 1.6	1.4	1.2	1.1	(1.5) 1.5	1.3	1.1	1.1	1.4	1.2	1.1	1.0	25
30		1.7	1.5	1.3	1.2	1.6	1.3	1.2	1.1	(1.5) 1.4	1.3	1.1	1.0	30
35		1.7	1.5	1.4	1.3	1.6	1.4	1.2	1.2	1.5	1.3	1.2	1.1	35
40		(2.0) 1.8	1.6	1.4	1.3	1.7	1.4	1.3	1.2	1.6	1.4	1.2	1.1	40
45		1.9	1.6	1.5		(2.0) 1.7	1.5	1.4	1.2	1.7	1.4	1.3	1.2	45
50		2.0	1.7	1.5		1.8	1.6	1.4		(2.0) 1.7	1.5	1.3	1.2	50
60		(2.5) 2.1	1.8			1.9	1.7	1.5		1.8	1.5	1.4		60
70		2.2	1.9			(2.5) 2.0	1.7	1.6		1.9	1.6	1.5		70
80		2.3				2.1	1.8			(2.5) 1.9	1.7			80
90		2.4				2.2	1.9			2.0	1.7			90
100		(3.0) 2.5				(3.0) 2.3				2.1	1.8			100
120		2.7				2.5				(3.0) 2.3				120
140		(3.5) 2.8				2.6				2.4				140
160						(3.5) 2.7				2.5				160
										(3.5)				

* Height, feet, required to carry flow with long grass in channel ("D" retardance), including 0.3-foot freeboard measured from the bottom of channel to a point 2 feet off the peak of the ridge. One foot is considered minimum height.

** Bottom width required to give desired velocity with sparse vegetation in channel ("E" retardance).

(1.0) Velocity, in feet per second, to be expected in channel with short, sparse vegetation ("E" retardance).

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EXTENSION CONTINUING EDUCATION The State is the Campus

Design Criteria For Debris Basins

James Steichen, Department of Agricultural Engineering
College of Agriculture

A debris basin provides storage for silt, sand, gravel, or other debris moving from adjacent lands. The debris causes damage when it moves with runoff water from its source on land adjacent to a landowner's farm, and deposits as sediment in his ponds, waterways, diversions, bottomland fields, or other developed areas. The landowner has no means of controlling the movement of the debris at its source on land adjacent to his farm and therefore must develop the debris basin on his own land to control the sediment before it causes damage.

Description

The debris basin consists of an earth dam or other barrier constructed across a drainageway or other suitable location for collecting sediment. The dam is provided with properly designed spillways to dispose of excess runoff water at safe velocities which will not damage the dam or other improvements.

The sediment basin is a small pool of water through which the runoff from the adjacent land must flow. As the silt-ladened runoff flows through the pool, it slows down and loses its capacity to carry the larger silt particles which drop out into the pool.

Capacity of Debris Basin

The capacity of the basin should be not less than the volume of sediment expected to be deposited in the pool during the planned useful life of the proposed improvements it is designed to protect. The capacity may be reduced where it is determined that periodic removal of the debris will be practical. In most cases the basin should have a capacity to contain an estimated 10-year sediment yield from the watershed area. In no case should the capacity be less than a 2-year yield. For cultivated land, the Universal Soil Loss Equation may be used in determining the soil loss. Use the following guidelines and Table 1 for determining the sediment yield from drainage areas of 100 acres or less.

Condition A (high sediment yield): Area may be similar to one of the following: (1) continuous row crop farmed with the field boundary (2) very little vegetative cover and with considerable active gully erosion.

TABLE I

SEDIMENT STORAGE CAPACITY FOR DEBRIS BASIN HAVING DRAINAGE AREA OF 100 ACRES OR LESS

(Based on 10-year sediment storage capacity)

Watershed Condition	Watershed Drainage Area Acres	Sediment Storage Capacity Acre Feet
A	5	0.6
	10	1.0
	20	1.6
	30	2.1
	40	2.6
	50	3.0
	60	3.4
	70	3.7
	80	4.1
	90	4.4
	100	4.8
B	5	0.4
	10	0.6
	20	1.0
	30	1.3
	40	1.6
	50	1.9
	60	2.1
	70	2.3
	80	2.6
	90	2.8
	100	3.0
C	5	0.2
	10	0.3
	20	0.4
	30	0.5
	40	0.6
	50	0.7
	60	0.8
	70	0.9
	80	1.0
	90	1.1
	100	1.2

Condition B (medium sediment yield): Area may be similar to one of the following: (1) half of the area meets Condition A and the remaining half is in permanent vegetative cover or small grain, (2) continuous cropland farmed on the contour, (3) rotation cropland with small grain and meadow, (4) non-cropland area with very little vegetative cover and no active gully erosion, (5) good permanent vegetative cover with very active gully erosion.

Condition C (low sediment yield): Area is in permanent vegetative cover with minor gully erosion.

This Guide prepared jointly by state and field staffs of College of Agriculture, University of Missouri-Columbia, and Soil Conservation Service. Original authors were Otto Griessel, SCS (retired), and R. P. Beasley, UMC (deceased).

Design Criteria

Earth Dam. Site investigation and design for the earth dam should be made in accordance with UMC Guide 1546, Designing and Constructing Earth Embankments.

Spillways. Design for the vegetative emergency spillway should be made in accordance with UMC Guide 1517, Emergency Spillways, Part II - Design. Detailed designs for mechanchanical spillways are found in the following UMC Guides:

1510 Design Criteria for Canopy and Hood Inlets
1511 Design Criteria for Morning Glory and Drop Inlets
1512 Design Criteria for Straight Drop Spillways
1514 Design Criteria for Formless Concrete Flumes
1518 Estimating Peak Rates of Runoff from Small Watersheds
1520 Discharge Capacity Tables for Canopy, Hood, and Drop Inlets.

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Designing and Constructing Earth Embankments

James Steichen, Department of Agricultural Engineering, College of Agriculture

Consider the following factors when designing and constructing earth embankments for farm ponds, irrigation reservoirs and grade stabilization structures.

Site Investigation

Suitability of a pond or reservoir site is dependent on the ability of the soils in the reservoir area to hold water and to provide a stable foundation for the embankment. Make a geologic investigation in areas where past experience indicates that permeable or unstable materials may be present in the soil.

Take soils borings or make test pits at intervals over the structure site. Frequency of the borings or test pits depends on the occurrence of significant changes in the soil profile. Dig or bore to sufficient depth to identify material that may be unstable or affect the ability of the structure to hold water. Consider another site if undesirable material is found.

Preparation of Site and Borrow Area

1. Remove all trees, stumps, trash, brush, sod, large roots, perishable material and loose soil from these areas.
2. Strip topsoil from the embankment foundation and borrow areas and deposit in storage piles.
3. After the stripping operation, scarify the ground surface within the foundation area to provide a bond between the foundation and earth fill.
4. Grade overhanging banks, pits, and holes within the foundation area to a 1 to 1 slope or flatter to provide bond with the fill.

Core Trench Construction

Excavate the core trench to a depth necessary to prevent seepage under the embankment. Construct the core trench with side slopes of 1 to 1 or flatter.

Backfill the core trench with the most impermeable material available at the site. The moisture content of the backfill material should be sufficient for good compaction. (When kneaded in the hand the soil should just form a ball which does not readily separate.) Keep the trench free of standing water during the backfill operations.

This Guide prepared jointly by state and field staffs of the College of Agriculture, University of Missouri-Columbia, and the Soil Conservation Service. R. P. Beasley was the original author.

Installation of Blanket

Pond basins containing a high percentage of coarse grained soils may require a blanket of less permeable material to prevent seepage. At some locations the topsoil may be less permeable than the subsoil. The less permeable material in the area should be stockpiled and spread as a blanket over the more permeable material in the pond basin. The blanket should be placed in 4-inch layers well compacted. A minimum thickness of 12 inches will be required in most cases. If a blanket is used over the entire pond basin a core trench is not required.

Installation of Principal Spillway Conduit And Stockwater Pipe

Place the conduit for the principal spillway and the pipe for the stock watering system, if needed, on solid foundations either (1) in trenches excavated in undisturbed soil or (2) on fill material placed in 6-inch layers and properly compacted. Install anti-seep collars on the conduit and on the stockwater pipe if needed. If no cradle is used under the conduit, shape the foundation to fit the conduit for a depth equal to 1/10 its diameter. Provide a uniformly firm bed throughout its length. For additional information see UMC Guide 1515 "Selecting Materials for and Installing Principal Spillways."

Design of Embankment

Top Width: Following are suggested minimum top widths for dams of various heights.

Height of Dam, feet.	*Minimum Top Width, feet.*
Under 10	8
10-20	10
21-30	12

If the top of the embankment is to be used as a roadway make the top width at least 12 feet.

Side Slopes: The side slopes on the settled embankment should not be steeper than 3 to 1 on the upstream side and 2 to 1 on the downstream side, except if based on previous favorable results on similar soils or on soil mechanics tests for stability, the minimum slope may be 2½ to 1 both upstream and downstream sides.

Flatter slopes should be used if necessary to insure the stability of the embankment or to facilitate mowing and maintenance.

Slope Protection: When the surface area of the reservoir exceeds 5 acres there are several methods of reducing wave erosion: (1) An 8-foot minimum width berm can be constructed on the upstream face of the embankment 0.5 foot above the crest of the principal spillway; or (2) a portion of the upstream slope of the embankment can be riprapped; or (3) the upstream slope of the embankment can be constructed to a 4 to 1 slope.

Use reed canary or other suitable grass or acquatic plants to protect berms from wave action.

Protect the upstream slope of reservoirs smaller than 5 acres from wave action with reed canary, other suitable grass, aquatic plants, riprap or other means as site conditions indicate.

Settlement: Provide sufficient overfill during construction to allow for settlement. If the material is placed in 6-inch layers at a moisture content sufficient for good compaction add 5 percent if compacted thoroughly with wheel scrapers or with rollers, add 10 percent if a bulldozer only is used. If material is quite dry or excessively wet, follow suggestions given in (2) "Construction of Embankment."

Freeboard: Freeboard is the difference in elevation between the water level in the emergency spillway when it is flowing at the design depth and the top of the settled fill. Provide a minimum freeboard of at least 1 foot. Be sure, however, that the difference in elevation between the crest (bottom) of the emergency spillway and the top of the embankment is not less than 1.5 feet if a principal spillway is used. If a principal spillway is not used and the 10-year frequency runoff through the spillway is over 10 cubic feet per second, or the embankment is over 5 feet high, or the surface area of the impoundment is over one-half acre, the difference in elevation between the crest (bottom) of the emergency spillway and the top of the embankment should be at least 2.0 feet.

Construction of Embankment

1. Be sure that the earth fill material does not contain any appreciable concentration of vegetation, roots, large rocks, frozen soil, or other foreign substances. Moisture content should be sufficient for good compaction. (When kneaded in the hand, the soil should just form a ball which does not readily separate.)

2. Place the fill material in approximately 6-inch layers that extend over the full width and length of the dam. Compact each layer by the operation of tractors, earth moving equipment, or rollers. If the moisture content of the fill material is deficient, sprinkle water on the surface of each lift of the fill material and thoroughly mix and compact prior to placing additional fill. If moisture content of the fill material is excessive do not use the fill material until it has air dried to proper moisture content.

3. Be sure that backfill adjacent to the pipe spillway and stockwatering system is free of rocks, clods or clumps. Place in 4-inch layers and tamp by hand or with mechanical tampers. Rubber-tired tractors may be used to supplement the tamping along the sides of the pipe and to provide a berm of compacted earth equal to the pipe diameter on each side of the pipe.

Bring backfill up approximately equal on each side of the pipe to prevent side movement of the pipe. Take care to prevent the pipe from uplifting when backfilling under the haunches. Do not drive heavy equipment over the pipe until a minimum of 2 feet of compacted fill has been placed over the top of the pipe.

4. Do not use frozen material in a fill and do not place fill material on frozen earth. When fill material starts to freeze during placement, stop construction until proper temperatures prevail. When it is desired to place fill on an area that is frozen, remove the frozen surface completely before placing additional fill.

5. At sites where there is a limited amount of impermeable fill material, (1) place this material in the core trench and the center section of the embankment and (2) place the least impermeable material in the downstream part of the embankment.

6. Allow sufficient overfill for settlement.

7. Place the topsoil material saved in the site preparation as a top dressing on the surface of the earth fill and emergency spillway.

8. Finish-grade the earth fill and emergency spillway to the dimensions and side slopes shown on the plans.

Establishment of Vegetation

Exposed surfaces of the earth spillway, embankment and borrow area not covered by the permanent pool should be fertilized, seeded and mulched to provide a good vegetative cover. See UMC Guide 4805 "Establishing and Maintaining Vegetation on Critical Areas."

Precautions To Prevent Seepage

Possibilities where seepage may occur from a water storage structure are shown in Fig. 1.

Take precautions indicated in Fig. 2 during site selection, investigation and construction to prevent seepage losses. Following is a listing of possibilities for seepage indicated by numbers circled in Fig. 1 and the suggested precautions or solutions.

1. Seepage through strata or pockets of permeable material. These may or may not be exposed during excavation.

Solution: Make a thorough site investigation prior to construction. Either move to another site or give special treatment to undesirable areas such as the compacted blanket of impervious material as in Fig. 2.

2. Seepage along roots and root cavities. If trees in the vicinity of the embankment are cut the roots will die, leaving cavities along which water will follow.

Solution: Remove all roots from the embankment area prior to construction.

3. Seepage along the plane between the original ground and the embankment.

Solution: Follow suggestions given under "Preparation of Site and Borrow Area."

4. Seepage under the embankment and through a layer of permeable material.

Solution: Block flow by construction of a core trench as suggested under "Core Trench Construction."

5. Seepage through the embankment.

Solution:

(a) Build the embankment with proper top width and side slopes.

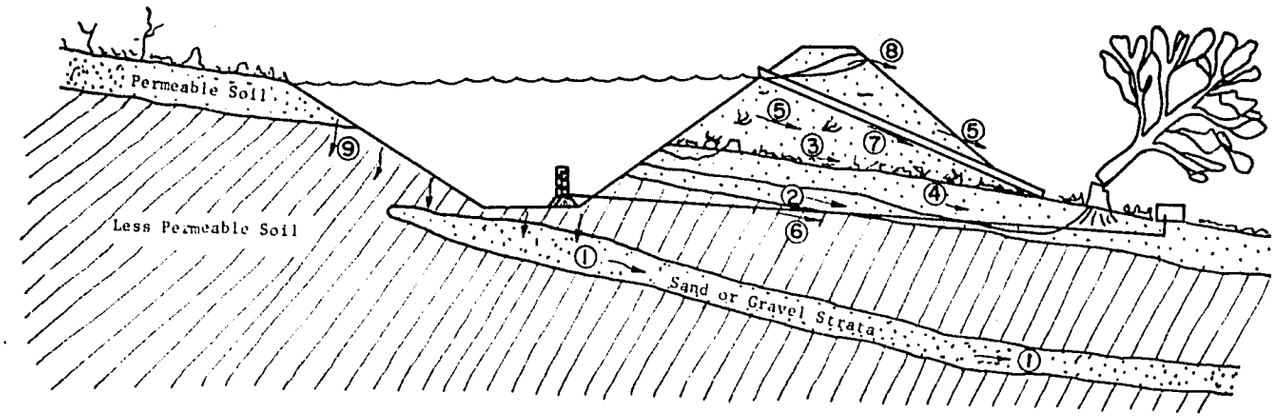

Figure 1. Possibilities where seepage may occur from a water storage structure.

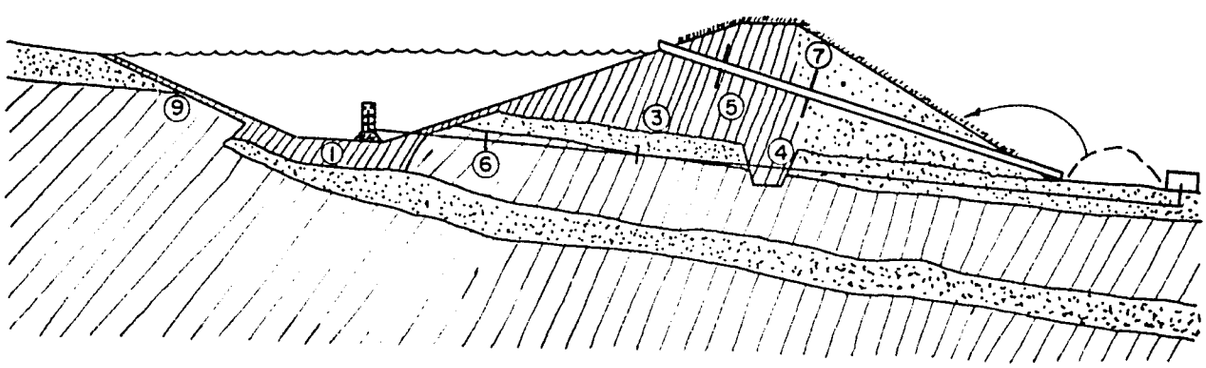

Figure 2. Precautions to take during construction of a water storage structure to prevent seepage.

(b) Remove all brush, roots and debris from the borrow area so it will not be deposited in the embankment.

(c) Place the less permeable material on the water side of the embankment and more permeable material in the downstream part.

(d) Place fill in thin layers and compact thoroughly.

(e) Follow other suggestions given in "Construction of Fill."

6. Seepage along stock water pipe.

Solution: Install anti-seep collars and compact earth around pipe.

7. Seepage along principal spillway conduit.

Solution: Install anti-seep collars in accordance with information in UMC Guide 1515 "Selecting Materials for and Installing Principal Spillways" and follow suggestions given under "Installation of Principal Spillway Conduit and Stock Water Pipe" discussed previously.

8. Flow through muskrat burrows and cavities created by other burrowing animals.

Solution: Build embankment with proper top width and side slopes. Design the spillways to reduce fluctuation of water level to a minimum. Keep the embankment cleared of brush and debris.

9. At those sites where the soil is permeable throughout the profile there may be seepage over the entire basin.

Solution: Scarify the basin area to a depth of 8 to 10 inches. Compact the loosened soil at optimum moisture content, to a dense layer. On more permeable soils install a blanket as discussed previously.

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Estimating Soil Losses in Northern Missouri

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Soil erosion varies considerably throughout the country. A method was needed to help predict annual soil loss from an individual's land.

The equation described below takes into account the variability in conditions such as rainfall, soil type, crop rotation, conservation practices used and topography. It was designed to help the individual farmer select practices that will reduce soil erosion.

This equation is used by the Soil Conservation Service in developing soil conservation programs. It is used also by engineers and architects to plan erosion control. Originally designed for farmland, it is, therefore, especially valuable to the farmer in planning his own soil conservation program.

New federal and state programs will encourage a more dedicated effort towards conserving the soil. Information included in this guide should be helpful in these programs.

Precautions

The equation estimates long-term average annual soil loss for a specific situation. It will estimate soil losses from sheet and rill erosion but not from gullies. It is unusual for all the soil loss predicted by this equation to be transported from a field. Some is deposited in terrace channels, waterways or in flatter areas. The value you calculate for your soil loss should be considered as a rough estimate only. However, it should point out alternative solutions to reducing your soil loss.

Factors Affecting Soil Loss

To develop an effective erosion control program, you should evaluate the factors affecting erosion and practices for its control. In planning your farm layout, select the combination of agronomic and mechanical practices that will best conserve your soil and provide you with an efficient business operation.

It is not possible to avoid all erosion loss, but there is a point where soil loss will be sufficiently small that crop production can be carried on and the productivity of the soil maintained or perhaps increased through the years. The most effective tool for evaluating soil losses was developed by the Agricultural Research Service and is often called the Universal Soil Loss Equation:

FIGURE 1. Average Annual Values of the Rainfall Factor (R)

$$A = R \times K \times LS \times C \times P$$

A = soil loss in tons per acre per year
R = rainfall factor
K = soil erodibility factor
LS = slope length and steepness factor
C = cropping-management factor
P = erosion control practice factor

Rainfall (R)

This factor is a measure of rainfall energy rather than just rainfall. A short, intense 4-inch storm will cause much more erosion than a slow, steady 4-inch rain. These R factors (See Figure 1) vary from about 200 in northern Missouri to about 250 in southern Missouri, where intense thunderstorms are more common. In northern Missouri, 50 percent of the year's erosive rainfall occurs in May, June and July.

Soil Erodibility (K)

Soil erodibility is a measure of the relative resistance to erosion of the soil itself. The larger the value of K, the easier that particular soil will erode. Generally sandy soils are less erodible than medium-textured soils.

Table 1 lists erodibility (K) and erosion tolerance (T) values for a broad grouping of several sloping upland soils. The first T value is an acceptable soil loss for that soil. Use the second T value if the soil already has been eroded severely.

Slope Length and Steepness (LS)

Slope (steepness or gradient) and slope length are two important factors that affect erosion. A relative value of 1.0 has been assigned to a 9 percent slope with a length of 73 feet. The effects of slope steepness and length have been combined into LS values as shown in Table 2. The average slope is estimated and found across the top of the table. The slope length is read on the side of the table and is the length from where flow begins to where sediment is deposited, or where runoff enters a well defined channel such as a terrace. For example, a 5 percent slope 100 feet in length has an LS value of 0.6, while a 14 percent slope of 300 feet in length has an LS value of 4.0.

TABLE 1. Erodibility (K) and Erosion Tolerance (T) Factors

	K	T
Marshall - Knox - Napier Deep loess soils adjacent to Missouri River bottom north and west of Glasgow	.32	5-4
Sharpsburg - Grundy - Ladoga - Pershing Moderately deep loess of west central Missouri	.37	3-2
Adair - Shelby - Armstrong - Gara Dark soil on slopes below loess deposits often used for forages and pasture	.28	3-2
Mexico - Putnam Claypan soils of northeast Missouri, level to moderately rolling	.40	3-2
Menfro - Winfield - Weldon River hills along Missouri River from central Missouri to St. Louis and Mississippi River hills north of St. Louis	.37	4-3
Lindley - Keswick - Hatton Sloping less fertile soils of north central and northeast Missouri, usually pasture or timber	.37	3-2

TABLE 2. Slope Steepness and Length Factor (LS)

Length of Slope (L) (in feet)	Percent Slope (S)															
	2	3	4	5	6	7	8	9	10	12	14	16	18	20	22	24
20	*	.2	.2	.2	.2	.4	.4	.6	.6	.8	1.0	1.2	1.6	1.8	2.2	2.6
30	.2	.2	.2	.2	.4	.4	.6	.6	.8	1.0	1.2	1.6	2.0	2.2	2.6	3.0
40	.2	.2	.2	.4	.4	.6	.6	.8	.8	1.2	1.4	1.8	2.2	2.6	3.0	3.5
50	.2	.2	.2	.4	.4	.6	.6	.8	1.0	1.2	1.6	2.0	2.4	3.0	3.5	4.0
60	.2	.2	.4	.4	.6	.6	.8	1.0	1.0	1.4	1.8	2.2	2.8	3.0	4.0	4.5
70	.2	.2	.4	.4	.6	.6	.8	1.0	1.2	1.6	2.0	2.4	3.0	3.5	4.0	5.0
80	.2	.2	.4	.4	.6	.8	.8	1.0	1.2	1.6	2.0	2.6	3.0	3.5	4.5	5.0
90	.2	.2	.4	.6	.6	.8	1.0	1.2	1.2	1.8	2.2	2.8	3.5	4.0	4.5	5.5
100	.2	.4	.4	.6	.6	.8	1.0	1.2	1.4	1.8	2.4	2.8	3.5	4.0	5.0	5.5
110	.2	.4	.4	.6	.8	.8	1.0	1.2	1.4	1.8	2.4	3.0	3.5	4.5	5.0	6.0
120	.2	.4	.4	.6	.8	.8	1.0	1.2	1.4	2.0	2.6	3.0	4.0	4.5	5.5	6.0
130	.2	.4	.4	.6	.8	1.0	1.2	1.4	1.6	2.0	2.6	3.5	4.0	5.0	5.5	7
140	.2	.4	.4	.6	.8	1.0	1.2	1.4	1.6	2.2	2.8	3.5	4.0	5.0	6.0	7
150	.2	.4	.6	.6	.8	1.0	1.2	1.4	1.6	2.2	2.8	3.5	4.5	5.0	6.0	7
160	.2	.4	.6	.6	.8	1.0	1.2	1.4	1.8	2.2	3.0	3.5	4.5	5.5	6.0	7
180	.2	.4	.6	.8	.8	1.0	1.4	1.6	1.8	2.4	3.0	4.0	4.5	5.5	7	8
200	.4	.4	.6	.8	1.0	1.2	1.4	1.6	2.0	2.6	3.5	4.0	5.0	6.0	7	8
250	.4	.4	.6	.8	1.0	1.2	1.6	1.8	2.2	2.8	3.5	4.5	5.5	7	8	9
300	.4	.6	.8	1.0	1.2	1.4	1.8	2.0	2.4	3.0	4.0	5.0	6.0	7	9	10
350	.4	.6	.8	1.0	1.2	1.6	1.8	2.2	2.6	3.5	4.5	5.5	7	8	9	11
400	.4	.6	.8	1.0	1.4	1.6	2.0	2.4	2.8	3.5	4.5	5.5	7	8	10	11
500	.4	.6	1.0	1.2	1.4	1.8	2.2	2.6	3.0	4.0	5.0	6.0	8	9	11	13
600	.6	.8	1.0	1.4	1.6	2.0	2.4	2.8	3.5	4.5	5.5	7	9	10	12	14
700	.6	.8	1.0	1.4	1.8	2.2	2.6	3.0	3.5	5.0	6.0	8	9	11	13	15
800	.6	.8	1.2	1.6	1.8	2.4	2.8	3.5	4.0	5.0	7	8	10	12	14	16
900	.6	1.0	1.2	1.6	2.0	2.4	3.0	3.5	4.0	5.5	7	9	10	13	15	17
1000	.6	1.0	1.2	1.6	2.2	2.6	3.0	3.5	4.5	5.5	7	9	11	13	16	18
1200	.8	1.0	1.4	1.8	2.4	2.8	3.5	4.0	4.5	6.0	8	10	12	14	17	20
1400	.8	1.2	1.6	2.0	2.4	3.0	3.5	4.5	5.0	7	9	11	13	16	18	21
1600	.8	1.2	1.6	2.2	2.6	3.5	4.0	4.5	5.5	7	9	11	14	17	20	23

ntour Limits—2 percent 400 feet, 8 percent 200 feet, 10 percent 100 feet, 14-24 percent 60 feet. The effectiveness of contouring beyond these limits is speculative.

pounds per acre of residue). For each bushel of small grain there are 100 pounds of residue (30 bushels per acre wheat equals 3,000 pounds per acre of residue). Soybean residue usually averages 1,500 to 2,500 pounds per acre. For sod residue, estimate the amount of hay the residue would make (3,000 pounds per acre gives optimum erosion control). (See Figure 2 for photos of varying amounts of surface residue.)

Compare the difference between continuous corn, spring plow, residue left with a C of 0.38 and continuous corn, no till (10 percent soil surface tilled) with 6,000 + pounds of residue with a C of 0.03. The reason for the large difference is that with no till (or other conservation tillage) the surface is protected 12 months of the year. With conventional tillage, spring plowed land is unprotected 3 or 4 months, while fall plowed land may be unprotected up to 9 months each year.

Unfortunately, few C values have been evaluated for many other reduced tillage systems such as chisel plow and till-plant systems. An estimate can be made by estimating the surface residue and using Table 5. A chisel plow will reduce surface residue from 20 to 50 percent, and a disc will reduce surface residue about 50 percent each time it is used.

Double cropping is also an effective way of reducing soil erosion, since a growing crop is always on the soil. Planting soybeans in wheat stubble not only saves time and moisture but also reduces soil erosion. Values of C for double cropping are not now available, but they certainly should be comparable to conservation tillage.

TABLE 5. "C" Factors for Annual Cover and Various Quantities of Mulch

Cover or Mulch	"C" Factor
bare areas	1.0
¼ ton straw mulch	.52
½ ton straw mulch	.35
¾ ton straw mulch	.24
1 ton straw mulch	.18
1½ ton straw mulch	.10
2 ton straw mulch	.06
3 ton straw mulch	.03
4 ton straw mulch	.02
annual cover	.15

Pasture, Range and Idle Land "C" Factor

Table 6 points out the importance of the amount and type of cover in pasture land. The greater the ground cover,

TABLE 6. "C" Factors for Permanent Pasture, Rangeland and Idle Land[1]

Vegetal Canopy		Cover That Contacts the Surface						
Type and Height of Raised Canopy[2]	Canopy Cover[3]	Type[4]	Percent Ground Cover					
			0	20	40	60	80	95-100
Column No.:	2	3	4	5	6	7	8	9
No appreciable canopy		G	.45	.20	.10	.042	.013	.003
		W	.45	.24	.15	.090	.043	.011
Canopy of tall weeds or short brush (0.5 m fall ht.)	25	G	.36	.17	.09	.038	.012	.003
		W	.36	.20	.13	.082	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.075	.039	.011
	75	G	.17	.10	.06	.031	.011	.003
		W	.17	.12	.09	.067	.038	.011
Appreciable brush or bushes (2 m fall ht.)	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.085	.042	.011
	50	G	.34	.16	.085	.038	.012	.003
		W	.34	.19	.13	.081	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.077	.041	.011
Trees but no appreciable low brush (4 m fall ht.)	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.087	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.085	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.083	.041	.011

[1] All values shown assume: (1) random distribution of mulch or vegetation, and (2) mulch of appreciable depth where it exists.

[2] Average fall height of waterdrops from canopy to soil surface: m = meters.

[3] Portion of total-area surface that would be hidden from view by canopy in a vertical projection, (a bird's-eye view).

[4] G: Cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 inches deep.

W: Cover at surface is mostly broadleaf herbaceous plants (as weeds) with little lateral-root network near the surface, and/or undecayed residue.

TABLE 7. "C" Factors for Woodland

Stand Condition	Tree Canopy % of Area[1]	Forest Litter % of Area[2]	Undergrowth[3]	"C" Factor
Well Stocked	100-75	100-90	Managed[4]	.001
			Unmanaged[4]	.003-.011
Medium Stocked	70-40	85-75	Managed	.002-.004
			Unmanaged	.01 -.04
Poorly Stocked	35-20	70-40	Managed	.003-.009
			Unmanaged	.02 -.09[5]

[1] When tree canopy is less than 20%, the area will be considered as grassland, or cropland for estimating soil loss.

[2] Forest litter is assumed to be at least two inches deep over the percent ground surface area covered.

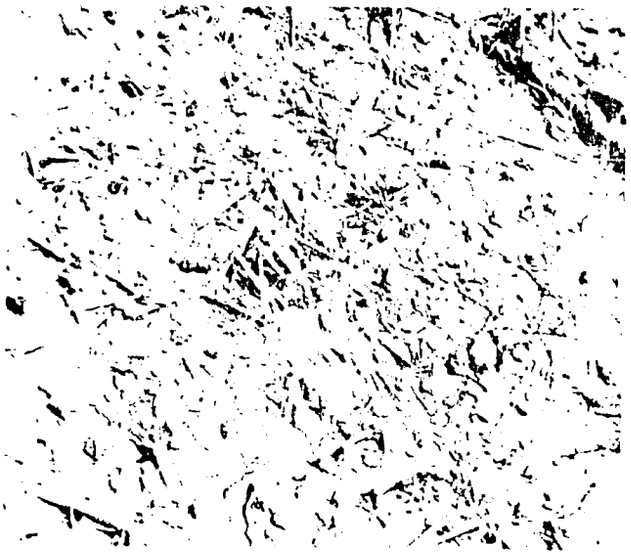
[3] Undergrowth is defined as shrubs, weeds, grasses, vines, etc., on the surface area not protected by forest litter. Usually found under canopy openings.

[4] Managed—grazing and fires are controlled.
Unmanaged—stands that are overgrazed or subjected to repeated burning.

[5] For unmanaged woodland with litter cover of less than 75%, C values should be derived by taking 0.7 of the appropriate values in Table 5. The factor of 0.7 adjusts for the much higher soil organic matter on permanent woodland

TABLE 8. "P" Factors for Erosion Control Practices

% Slope	Up-Down Hill	Contouring	Contour Strip Cropping
2-7	1.0	0.5	0.25
7-12	1.0	0.6	0.30
12-18	1.0	0.8	0.40
18-24	1.0	0.9	0.45

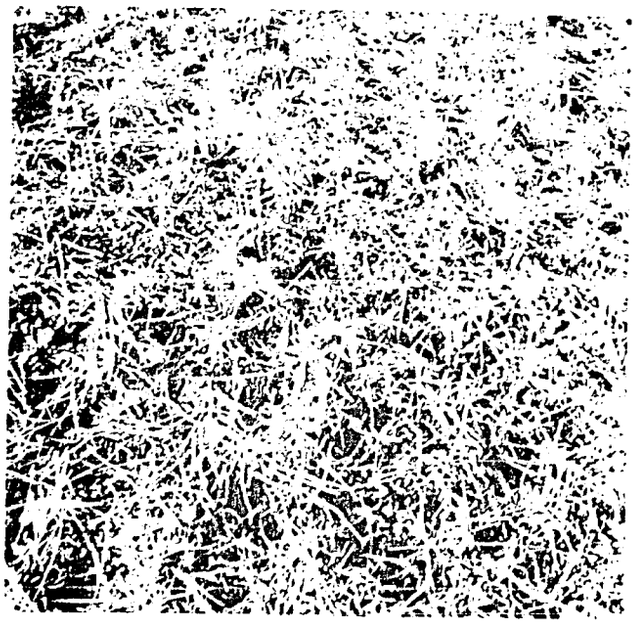


Corn Residue at 1,000 lb/A.

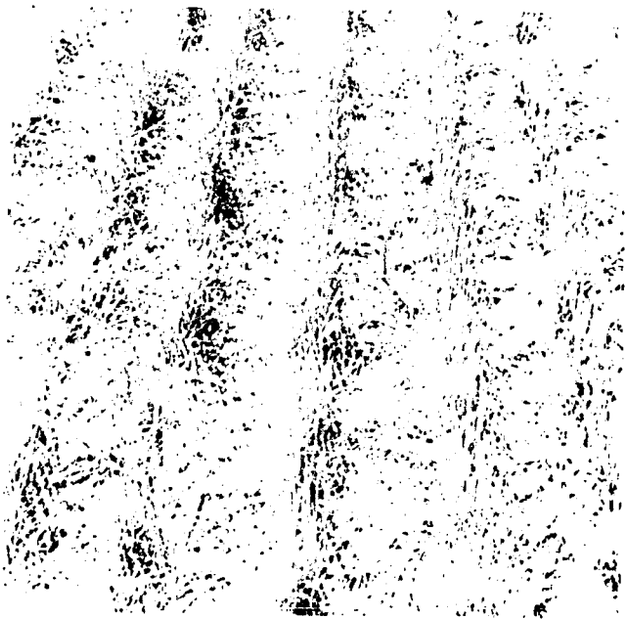
Corn Residue at 2,800 lb/A.

Corn Residue at 5,800 lb/A.

Corn Residue at 6,700 lb/A.



Soybean Residue at 2,800 lb/A.



Wheat Residue at 2,500 lb/A.

FIGURE 2. Varying Amounts of Surface Residue

Photographs courtesy of USDA Soil Conservation Service

TABLE 3. "C" Factors for Cropland—Conventional Tillage

Cropping System	Spring Plow, Residue Left	Fall Plow, Residue Left	Spring Plow, Residue Removed*	Fall Plow, Residue Removed*
Cont. Sb**	.42	.46	.54	.58
CSb**	.40	.44	.52	.56
CCSb**	.39	.43	.51	.55
Cont. C.	.38	.42	.50	.54
CCOx	.24	.27	.27	.30
CCWx	.22	.26	.24	.28
COx	.17	.19	.21	.23
CWx	.15	.17	.19	.21
CCCOM	.15	.17	.19	.21
CCCWM	.14	.16	.18	.20
CCOM	.12	.13	.18	.19
CCWM	.12	.13	.16	.17
CxCOM	.11	.12	.15	.16
CxCWM	.11	.12	.14	.15
CCOMM	.10	.11	.14	.15
CCWMM	.095	.11	.13	.14
CxCOMM	.090	.10	.10	.11
CxCWMM	.089	.10	.11	.12
CCOMMM	.082	.09	.12	.13
CCWMMM	.079	.09	.11	.12
CxCOMMM	.076	.085	.10	.11
CxCWMMM	.075	.085	.093	.103
COWMM	.067	.075	.091	.101
COM	.060	.070	.097	.107
CWM	.052	.060	.088	.096
COMM	.046	.050	.074	.078
CWMM	.040	.050	.067	.077
CWMMM	.033	.037	.054	.058
CWMMMM	.028	.032	.046	.050

C = Corn - Sb = Soybeans W = Winter grain M = Meadow
O = Spring grain X = Cover or green manure crop
* Residue removed includes corn stover and grain stover.
** Rotations with soybeans are calculated with 1500 pounds residue for each year of soybeans.
A factor for plow planting may be calculated by multiplying the factor for conventional tillage by 0.6.

Cropping Management (C)

Vegetative cover, crop rotation, fertility level, tillage practices, crop residue management and related conditions have an important effect on erosion. All of these factors are involved in developing a C factor. Selection of the correct C factor is more difficult because there are so many more choices. However, changing the C factor of your farming system is one of the easiest, yet still very effective, ways of reducing soil loss. When comparing these values, remember C = 1.0 for a tilled, continuously bare field.

The factors in Tables 3 and 4 take into account the stage of plant growth and condition of soil surface throughout the year, as well as the timing of erosive rains.

Conventional Tillage "C" Factor

The information in Table 3 was developed for a conventional moldboard plow system with various crop rotations and a high level of fertility. High fertility would mean an average yield of 75+ bushels per acre of corn. For lower fertility fields, soil loss may be 10 to 25 percent greater.

The C value increases as the hazard for erosion increases. Notice the effect of plowing season and whether residue was removed or not. For continuous corn, the C factor increases from 0.38 for spring plow and residue left to 0.54 for fall plow and residue removed, a 42 percent increase. Notice that close-growing crops such as wheat and meadow reduce the C factor. Continuous wheat has a C value of 0.21, which is 55 percent of fall plowed and residue left continuous corn.

Reduced Tillage "C" Factor

As the amount of residue increases and is left on the surface, the hazard of erosion is decreased. Table 4 has the C values for strip tilled (33 percent soil surface tilled) and no tillage (10 percent soil surface tilled) farming systems.

To estimate amount of residues from crop yields, consider that for each pound of corn produced there is 1 pound of residue (100 bushels per acre of shelled corn equals 5,600

TABLE 4. "C" Factors for Cropland—Conservation Tillage

	33% Soil surface tilled							10% Soil surface tilled						
	ROW CROP RESIDUE*					SOD RESIDUE**		ROW CROP RESIDUE*					SOD RESIDUE**	
CROPPING SYSTEM	1500 lb	2000-3000 lb	3000-4000 lb	4000-6000 lb	6000+ lb	2000-3000 lb	3000+ lb	1500 lb	2000-3000 lb	3000-4000 lb	4000-6000 lb	6000+ lb	2000-3000 lb	3000+ lb
Cont.R***	.311	.243	.188	.131	.080	.034	.027	.249	.192	.130	.070	.030	.016	.008
RRROx	.287	.245	.194	.173	.131	.037	.032	.251	.198	.155	.135	.102	.024	.018
RROx	.253	.223	.200	.177	.161	.038	.033	.229	.205	.181	.165	.123	.028	.021
RRROM	.197	.156	.123	.089	.058	.031	.027	.160	.125	.088	.052	.028	.020	.015
RROM	.168	.134	.107	.078	.053	.030	.026	.138	.109	.078	.048	.028	.021	.017
RROMM	.136	.109	.087	.064	.043	.025	.022	.111	.088	.063	.039	.023	.018	.015
RROMMM	.114	.091	.073	.054	.037	.022	.019	.093	.074	.054	.034	.020	.016	.013
ROM						.028	.026						.022	.020
ROMM						.023	.021						.018	.016
ROMMM						.019	.018						.015	.014
ROMMMM						.017	.015						.014	.013

The quantities of crop residue listed above refer to the amounts of cover in pounds per acre still remaining on the soil surface after planting.
* When meadows or green manure crops are included in the rotation, the calculations are based on plowing in the conventional manner for the first year corn and the balance of the years of corn are mulch tilled.
** When planted in sod residue, calculations are based on planting in sod without plowing for first year corn. All succeeding corn is planted with 6000+ lbs of residue cover.
*** R = Corn or Soybeans. The amount of residue produced by the crop determines the erosion potential.

the lower the C value. Also notice that grass type cover gives greater protection than weeds.

A tall fescue pasture with an excellent stand of grass would have no appreciable raised canopy, cover that contacts the ground is grass or G and percent ground cover is 95-100. The C factor is 0.003.

A bluegrass pasture with a poor stand of grass would have a raised canopy of tall weeds with a 25 percent canopy cover; the grass covers 60 percent of the ground. The C factor is 0.038.

Woodland "C" Factor

Soil erosion from wooded areas is almost always very low. Use Table 7 to find the appropriate C value.

Erosion Control Practices (P)

Erosion control practices include contour tillage, contour strip-cropping and terracing. Contouring and strip-cropping have been assigned P values depending upon slope and are given in Table 8.

Contouring is the practice of planting all row crops and performing all tillage across the slope. It is most effective on slopes from 2-7 percent where it reduces erosion 50 percent as compared to up and down hill farming. To get full benefit of contouring, fields should be relatively free of gullies and waterways should be grassed. Slope length limits for contouring are given in Table 9.

Contour strip-cropping is the practice of alternating strips of sod with row crops or small grain, all planted on the contour. The sod strips trap much of the sediment, and soil loss from the field is only one half that of contouring alone. Strip widths range from 60 feet on steep (13 to 18 percent) slopes to 100 feet for 2 to 7 percent slopes. Actual width can be adjusted to fit machinery size. Strip-cropping is not a common practice in Missouri, but it is another alternative.

Terracing is a very effective means of erosion control, because it effectively divides the slope into segments equal to the terrace spacing. Much of the effectiveness of terraces is due to reducing the LS factor in the soil loss equation. With terracing, as much as 90 percent of the soil moved to the channel will stay in the channel. This soil is not lost from the field and may result in extra terrace maintenance.

If the crop is planted on contour with the terraces, use a P value from Table 8. This will estimate the soil loss between terraces. Only about 20 percent of this will finally be lost from the field. The remainder will be trapped in the terrace channel and waterway.

TABLE 9. Slope - Length Limits for Contouring

Land Slope (%)	Maximum Slope Length (in feet)
2	400
4-6	300
8	200
10	100
12	80
14-24	60

Applications of the Soil Loss Equation

The primary purpose of the soil loss equation is to help select adequate soil and water conservation practices for farm fields. The following example will illustrate the use of the equation.

Given: Assume a field in Knox county on Mexico silt loam (claypan type) soil with a 3 percent slope, 300 feet long. Corn and soybeans are rotated. The field is spring plowed up and down the slope and the residues are turned under. Yields are usually greater than 75 bushels of corn.

Calculate the average annual soil loss. A = R x K x LS x C x P.

R = 200	Figure 1
K = 0.40	Table 1
LS = 0.6	Table 2
C = 0.40	Table 3
P = 1.0	Table 8

A = 200 x 0.40 x 0.6 x 0.4 x 1.0
= 19.2 tons per acre per year

This soil loss is well in excess of the tolerable soil loss (T) of 3 tons per acre per year. At this rate an inch of top soil would be lost in an average of 8 to 10 years.

Management decisions influencing soil loss are usually made by affecting C or P in the equation. The factor L can be changed by terracing. The other factors R, K and S are essentially fixed. If the tolerable soil loss (T) is substituted for A, the required CP factor can be found. Using the previous example:

$$C \times P = \frac{T}{R \times K \times LS}$$

$$C \times P = \frac{3}{200 \times 0.40 \times 0.6} = 0.06$$

If planting and tillage are done on the contour, P = 0.5, then for C x P to equal 0.06, choose a system with a C factor of 0.12 or less. From Table 3 with the same spring plow tillage as before a rotation of corn, corn, wheat, meadow will lower C to 0.12. By using conservation tillage the C factor can be reduced to an acceptable level by maintaining 1½ tons of mulch per acre (See Table 5). Using no till (10 percent surface tilled, Table 4) with 6,000+ pounds of residue per acre with continuous row crop has a C of 0.03. Therefore, soil loss would average one half the goal of 3 tons per acre per year, even without contouring.

Summary

The Universal Soil Loss Equation was presented as a means to estimate soil loss, to point out factors that cause erosion, and to present alternatives for controlling erosion. The use of contouring, as well as reduced tillage systems that maintain much of the crop residue on the surface, can reduce soil loss to acceptable levels in many cases. Terraces and waterways will still be needed for many other situations.

A workable soil and water conservation plan will usually be a combination of all these various parts. Considerable thought should be used so that you can develop the best plan that fits into your overall goals.

Issued in furtherance of Cooperative Extension Work Acts of May 8 and June 30, 1914 in cooperation with the United States Department of Agriculture. Carl N. Scheneman, Vice President for Extension, Cooperative Extension Service, University of Missouri and Lincoln University, Columbia, Missouri 65201.

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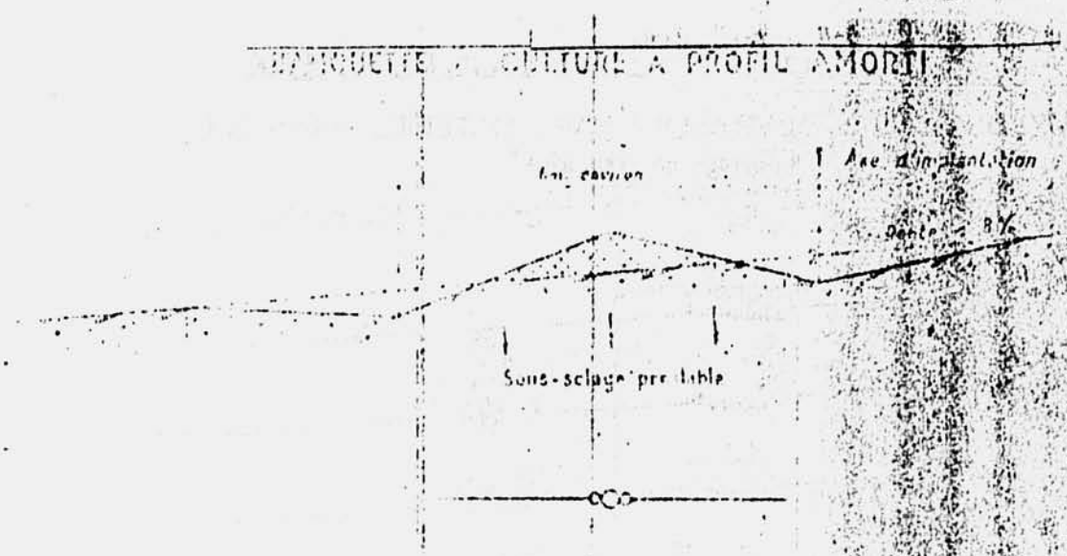
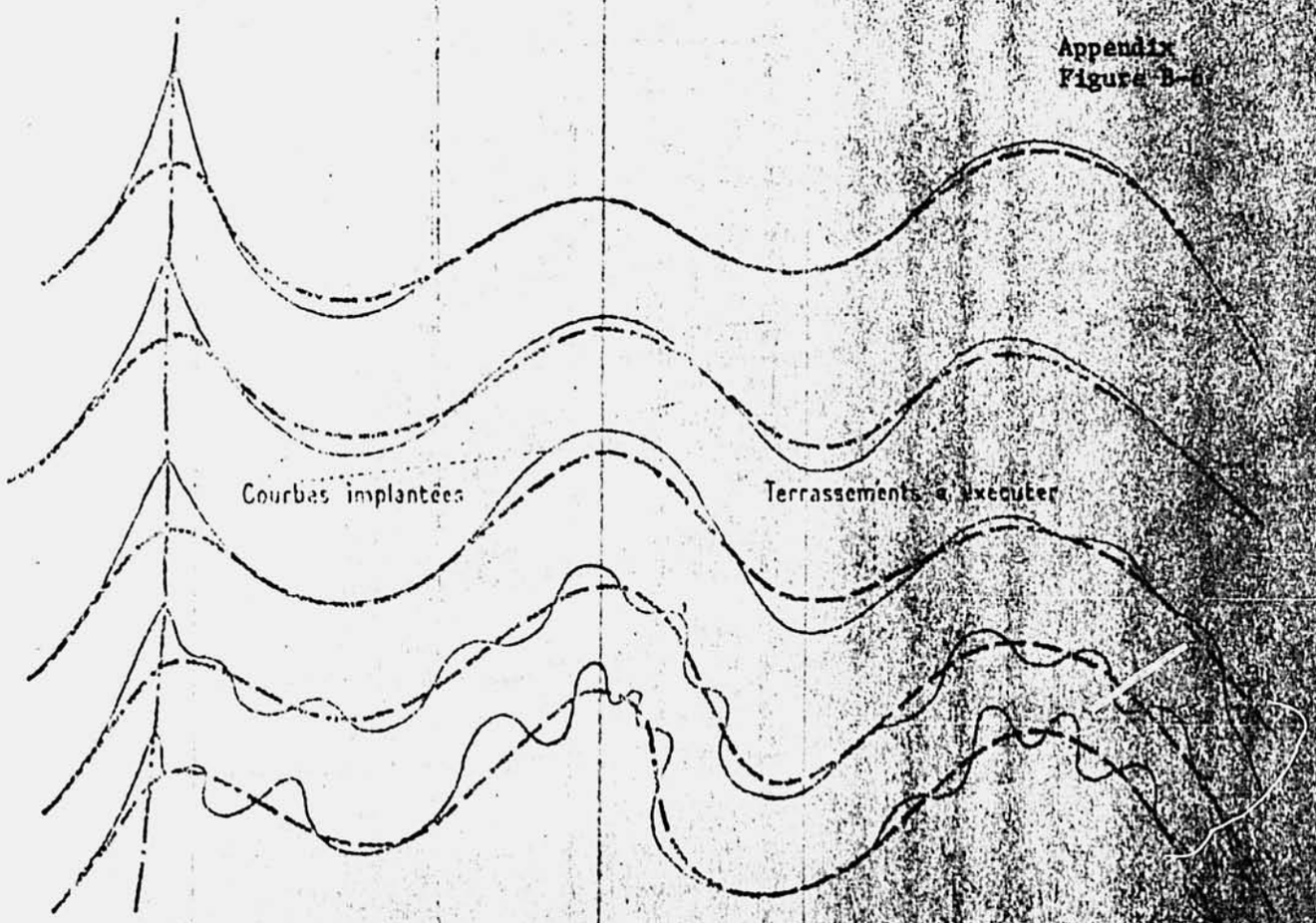


MODE D'EXECUTION PROJET C.E.S EN CULTURES ANNUELLES

(Terrasses, banquettes, courbes de niveau)

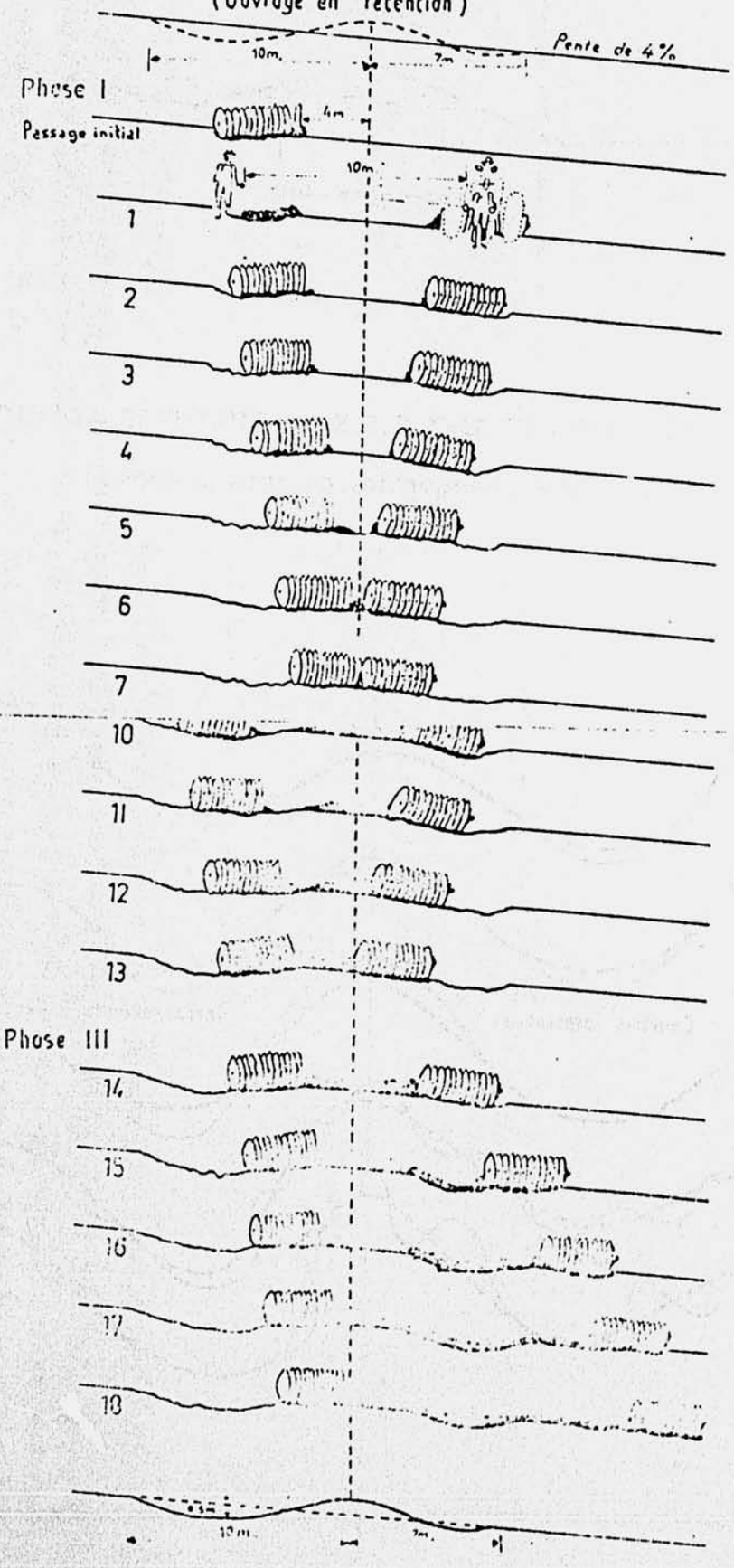
Appendix
Figure B-6



TRAVAUX SEMI-CULTURAUX

EXECUTION D'OUVRAGES PAR MATERIEL AGRICOLE

(Ouvrage en rétention)

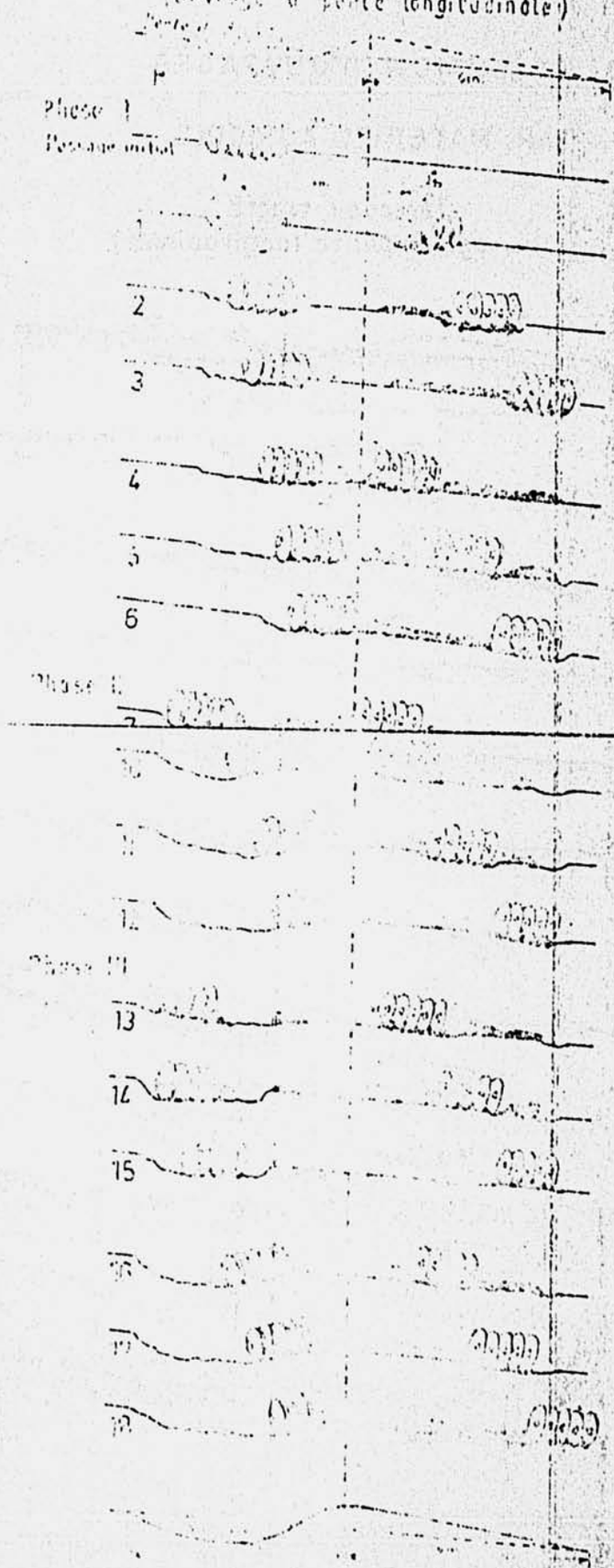


Appendix
Figure B-7

TRAVAUX SEMI-CULTURAUX

EXECUTION D'OUVRAGES PAR MATERIEL AGRICOLE

(Ouvrage à pente longitudinale)



Appendix
Figure B-8

Appendix
Figure B-9

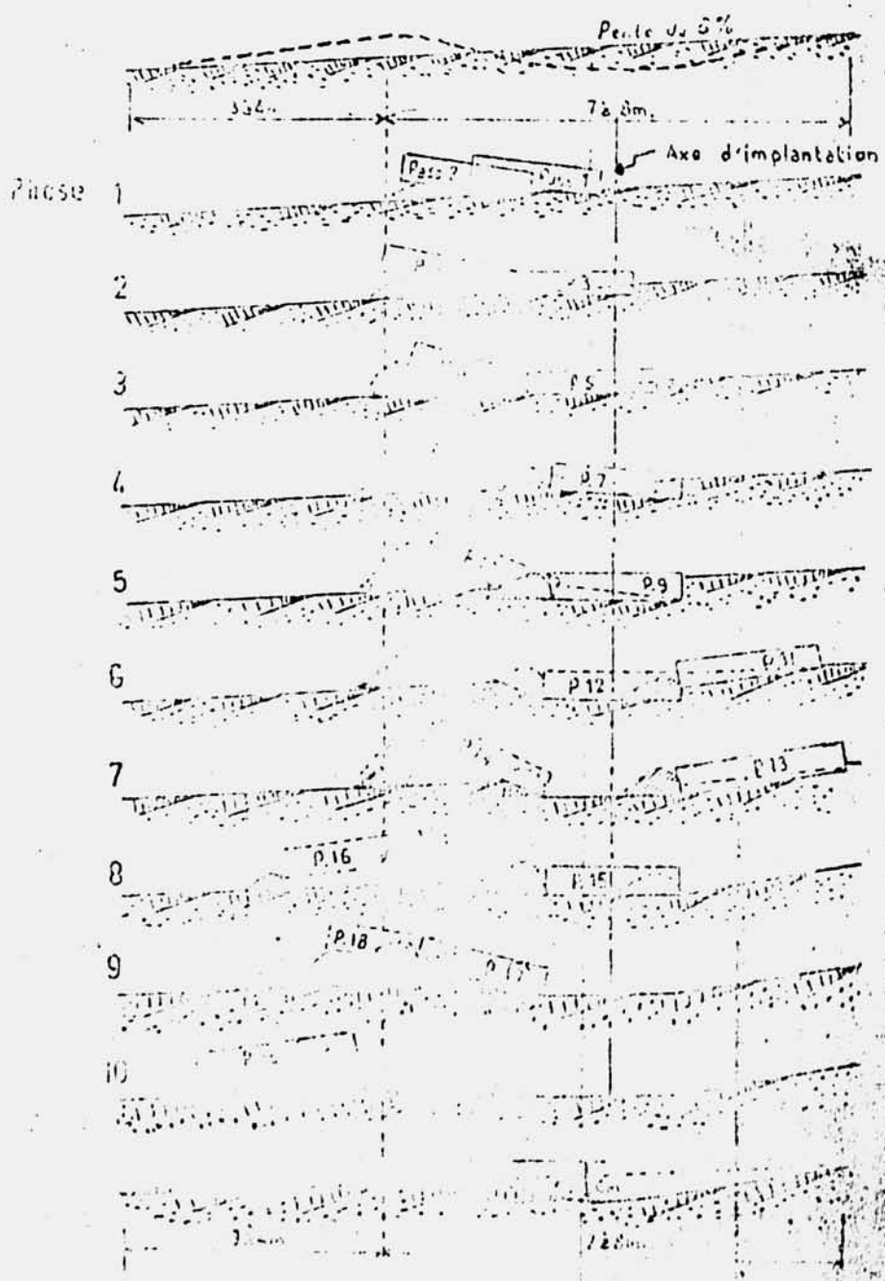
CULTURAUX

—oOo—

EXECUTION D'OUVRAGES

PAR MATERIEL AGRICOLE

Terracer tracté
(Ouvrage à pente longitudinale)

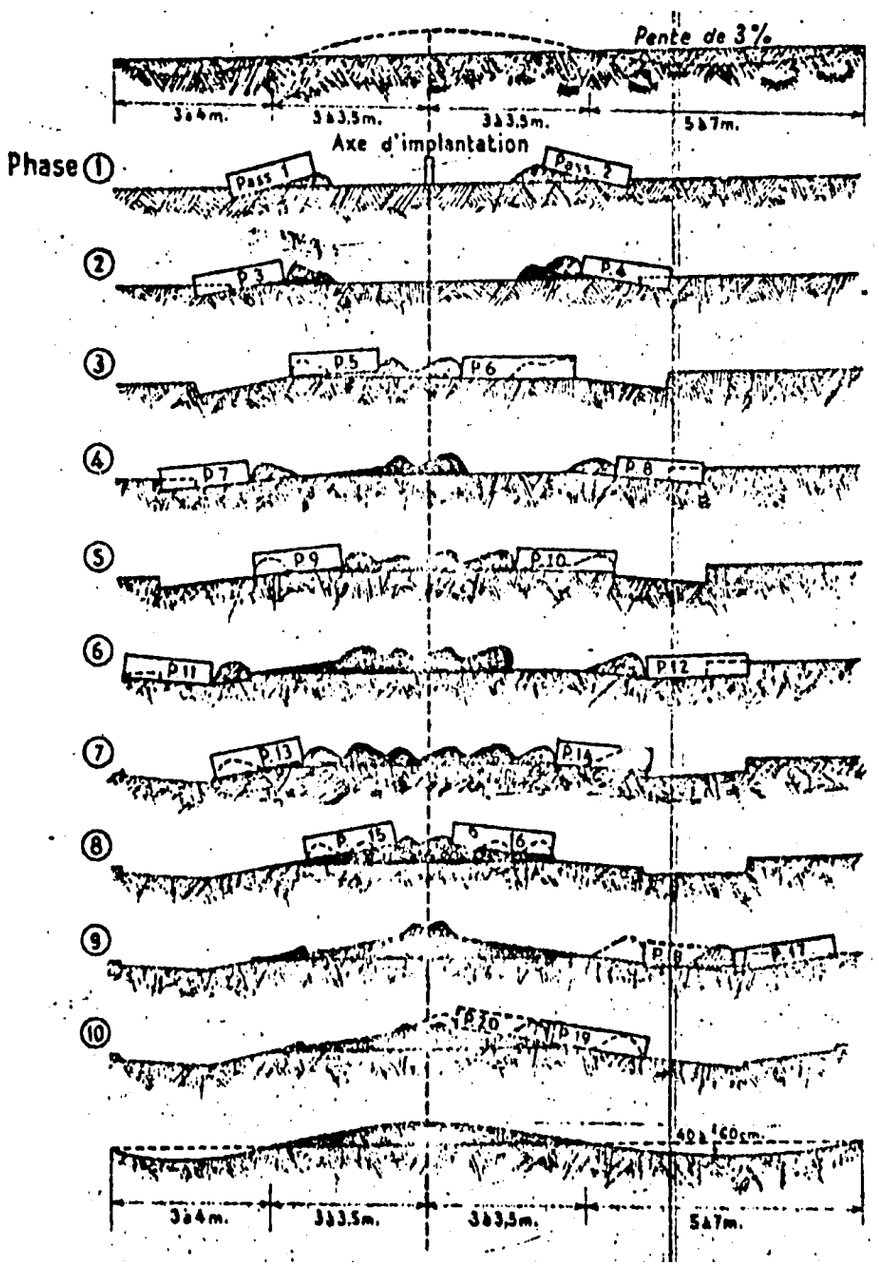


TRAVAUX SEMI-CULTURAUX

EXECUTION D'OUVRAGES PAR MATERIEL AGRICOLE

(Terracer Tracté
Ouvrage en rétention)

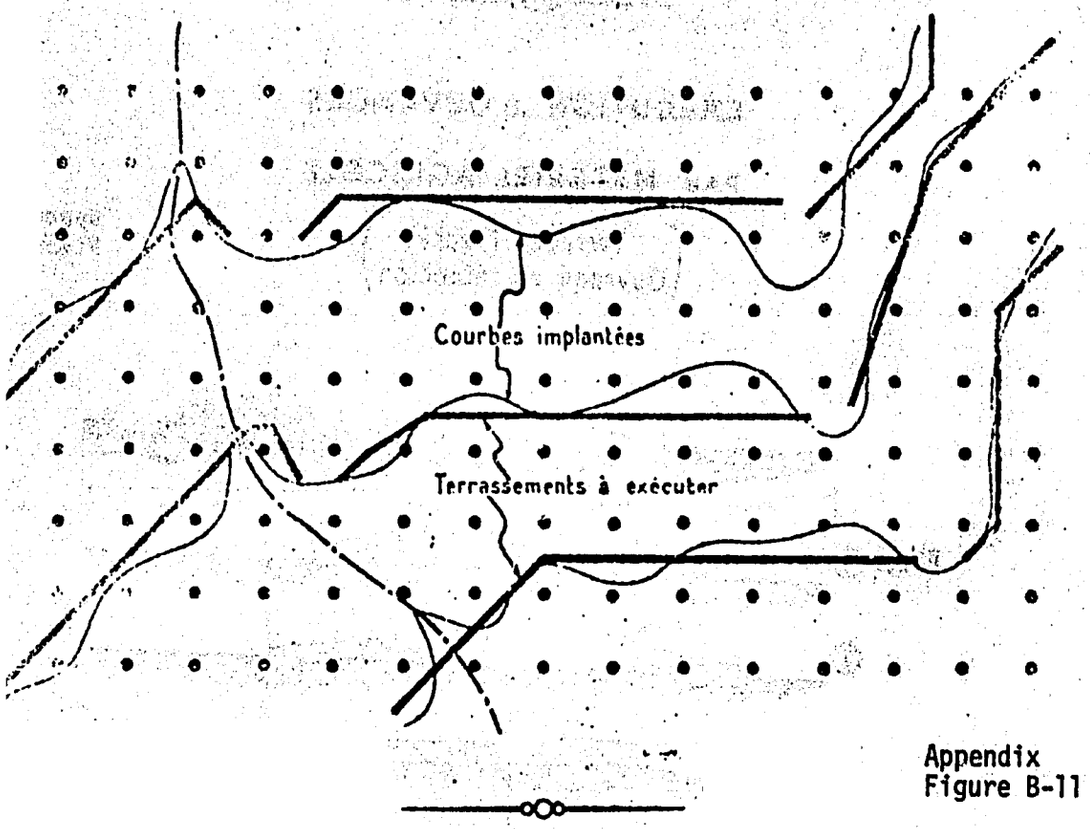
Appendix
Figure B-10



Appendix Figure B-11

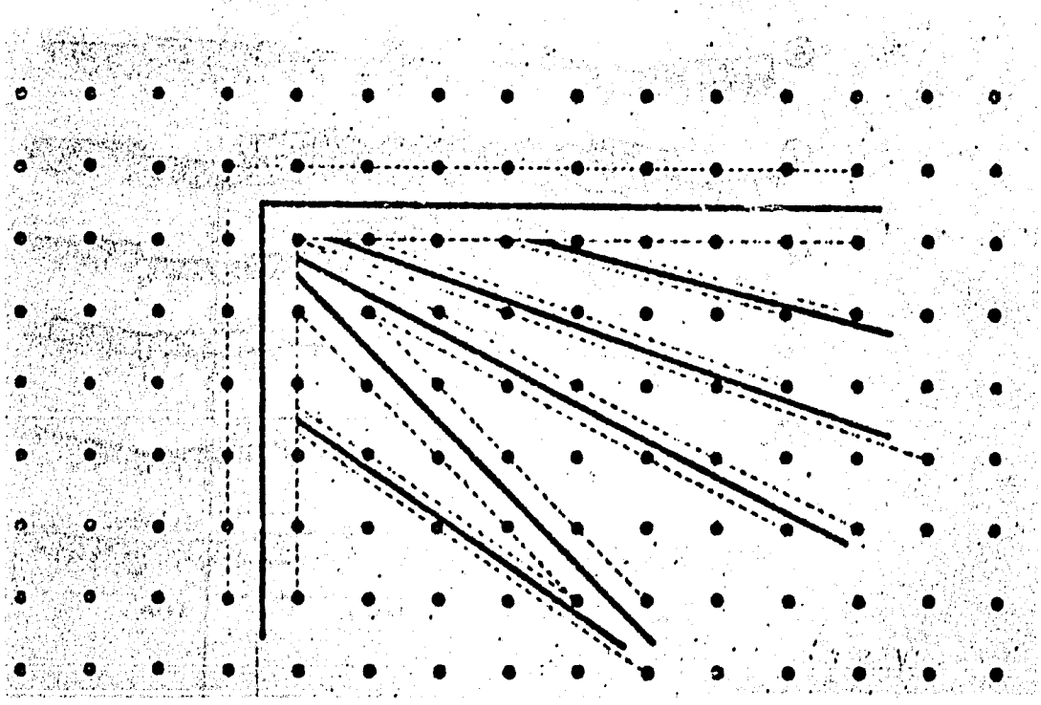
MODE D'EXECUTION PROJET C.E.S. EN PLANTATION EXISTANTE

(Terrasses, banquettes, courbes de niveau)



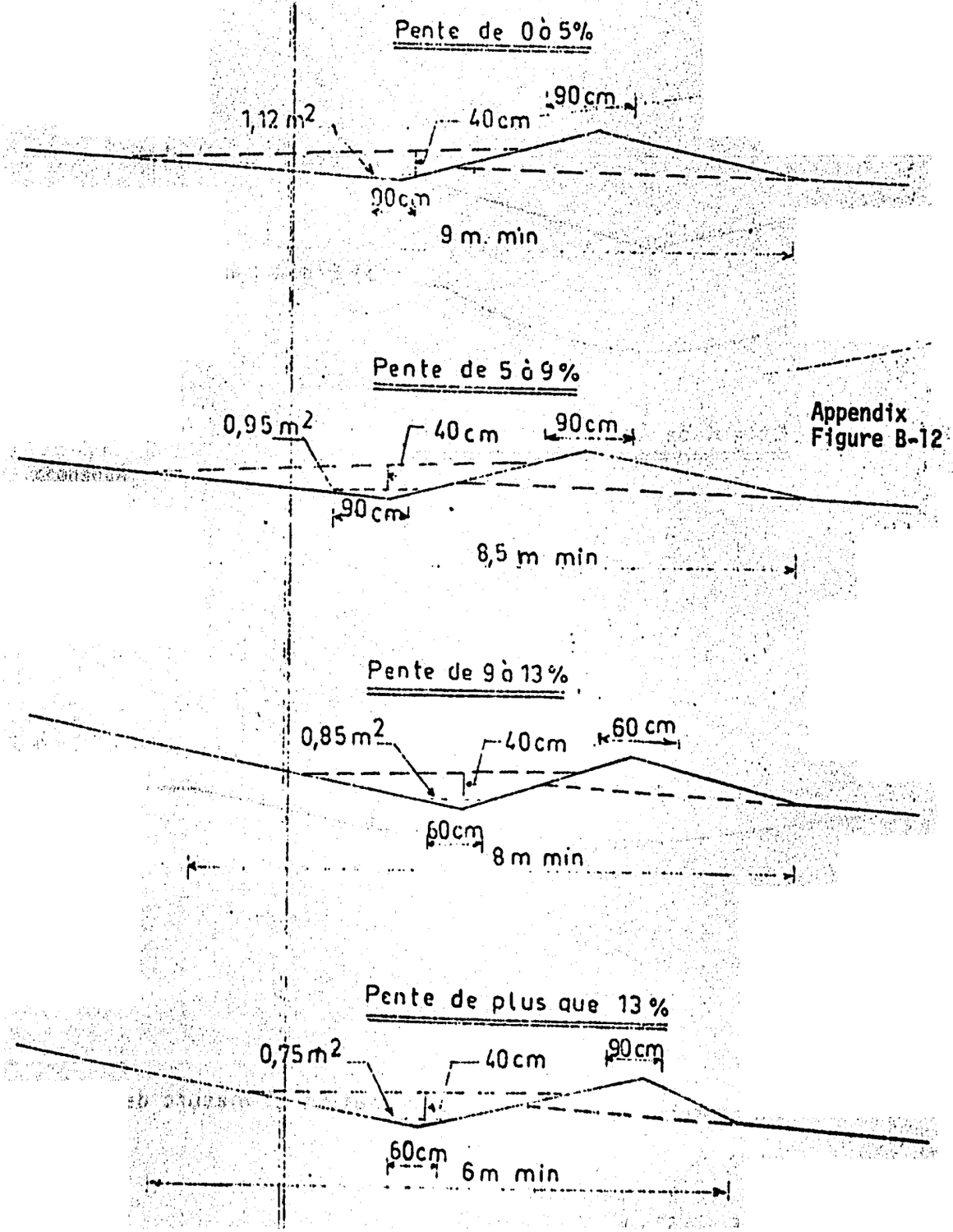
Appendix
Figure B-11

ALIGNEMENTS POSSIBLES
DANS UNE PLANTATION ARBUSTIVE



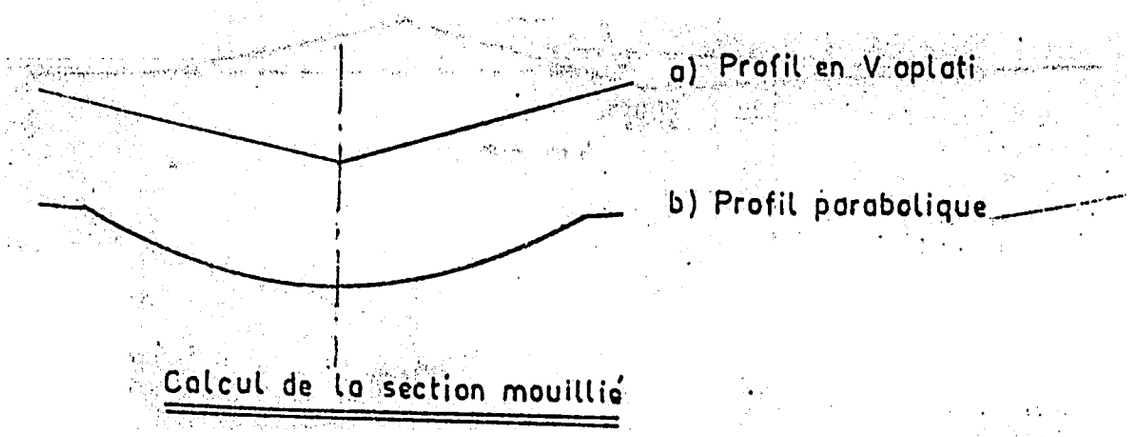
Appendix Figure B-12

BANQUETTES A RETENTION TOTALE

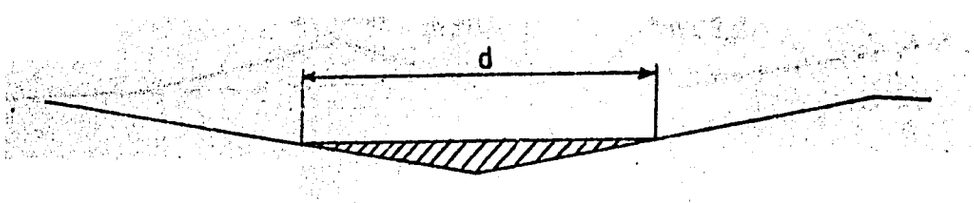


Appendix Figure B-12

TRAITEMENT A EXUTOIRES



Appendix
Figure B-13

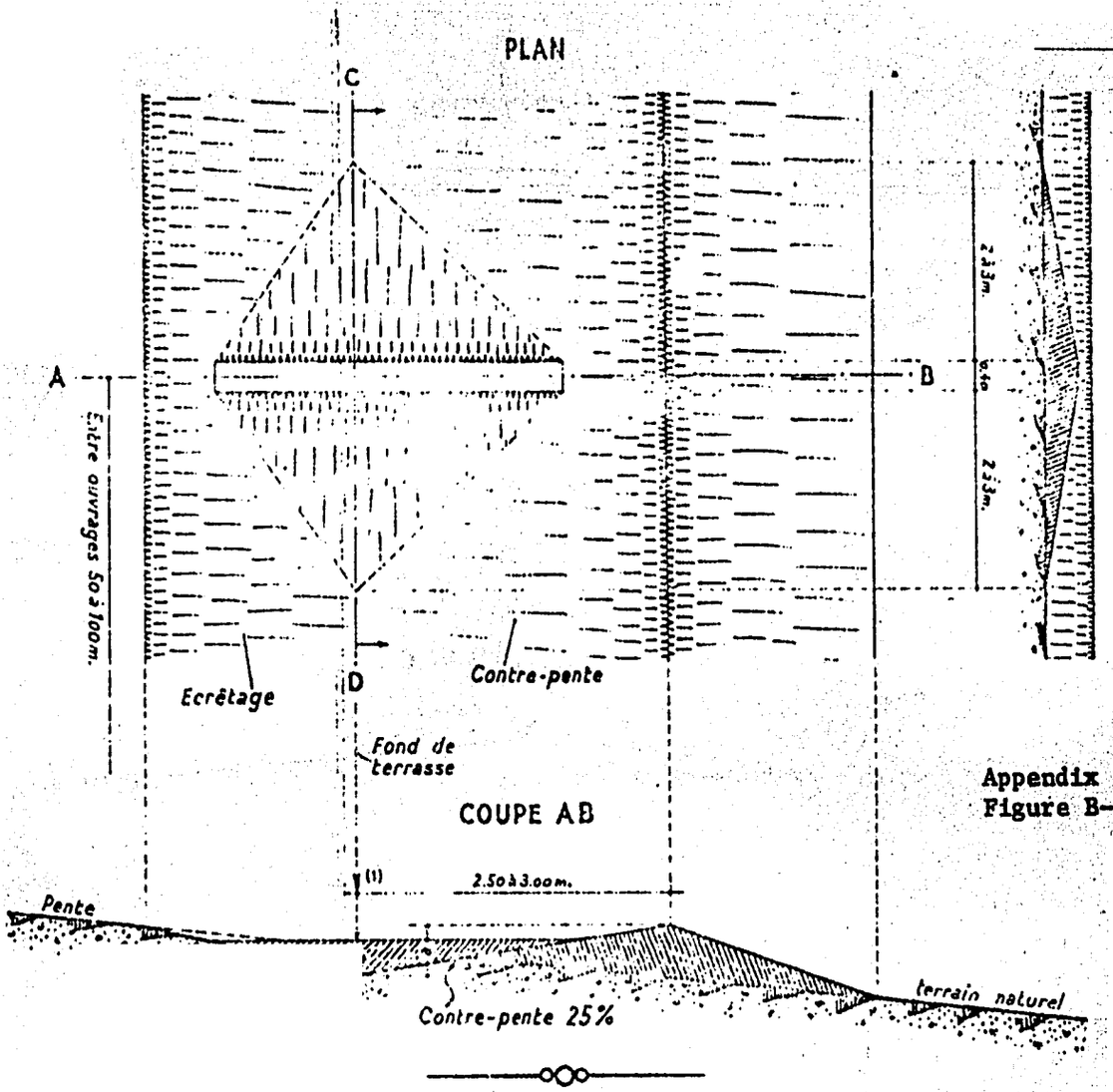


On cherche L ou H par approximation et mesure de terrain

a) $S = h\frac{l}{2}$ $\quad l = \frac{2S}{h}$

b) $S = 0{,}67\,Lh$ $\quad L = \frac{S}{0{,}67\,h}$

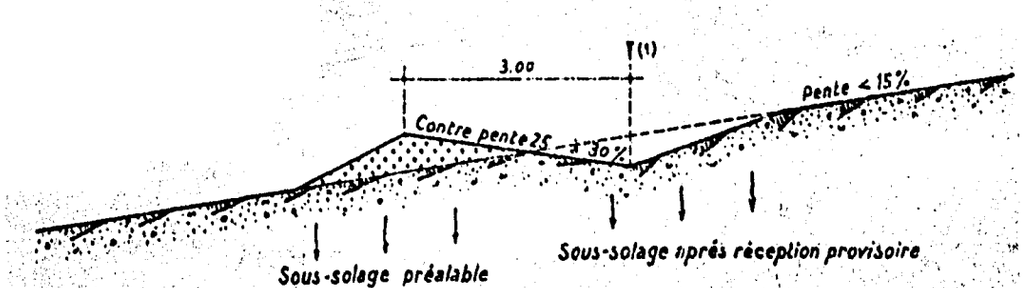
CLOISONS D'OUVRAGE EN RETENTION



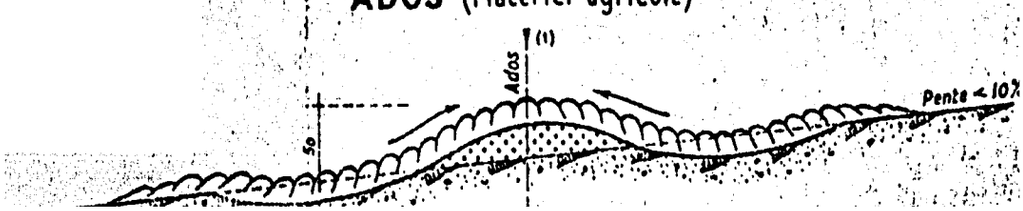
Appendix
Figure B-14

CULTURES ANNUELLES

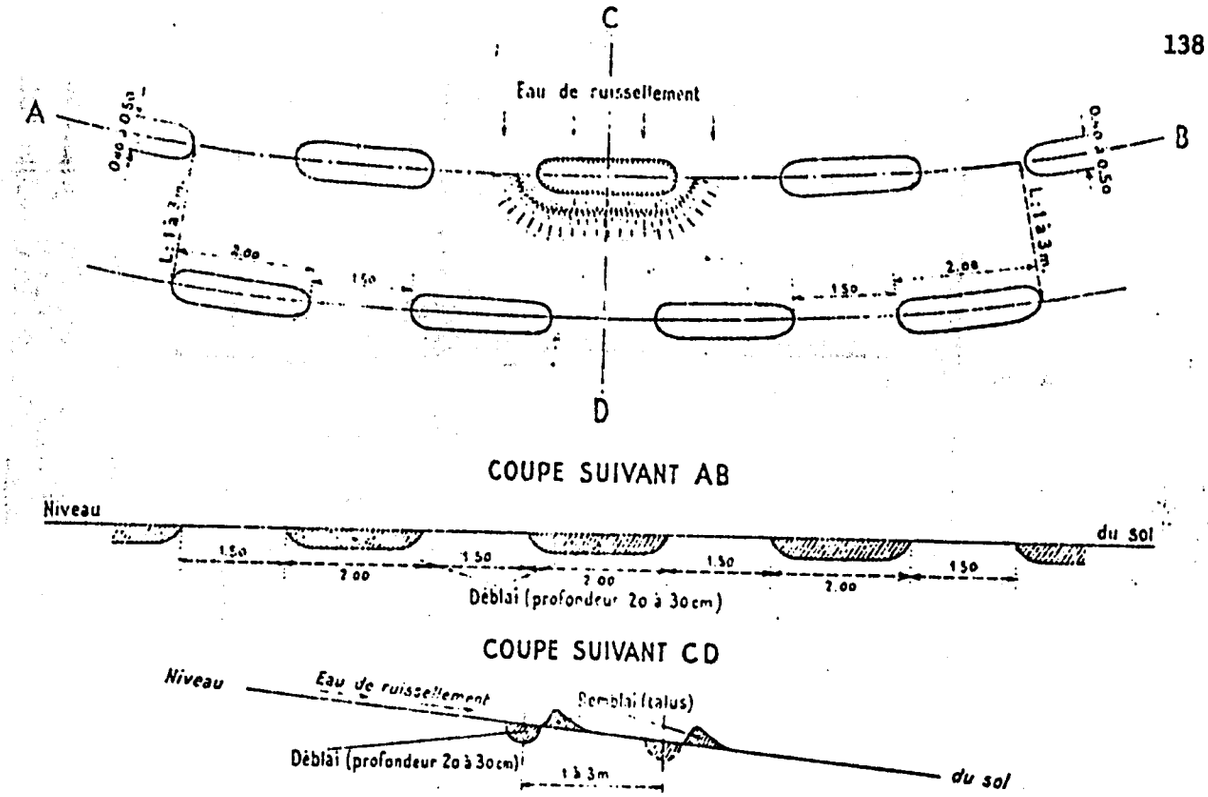
BANQUETTE DE CULTURE



ADOS (Matériel agricole)

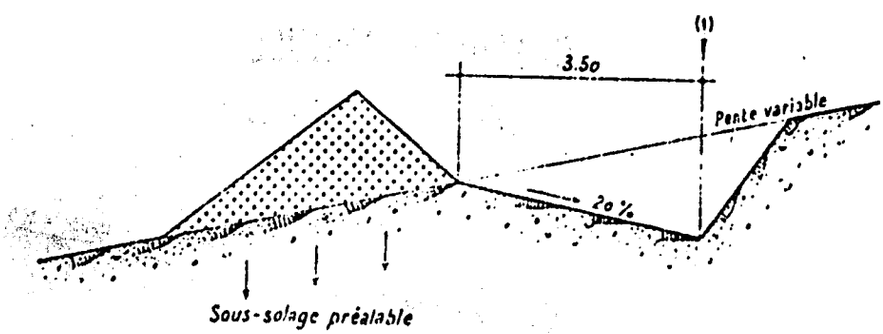


Appendix Figure B-19 BALCONNETS (Livre Bugeat)

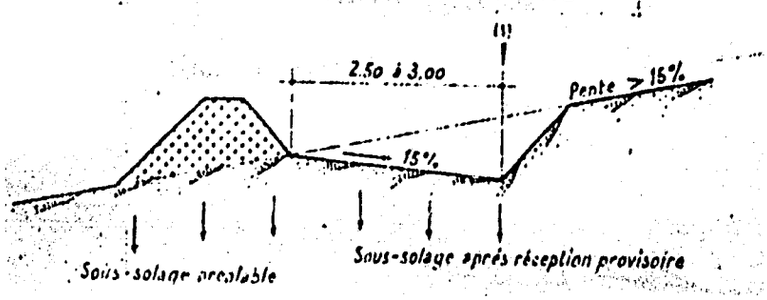


PLANTATIONS

FOSSÉ DE GARDE



TERRASSE DE PLANTATIONS



APPENDIX SECTION C

Reference Data for Cereal Crop (Barley-Wheat) Interventions in Dryland Areas

Appendix Table No.	Title	Page No.
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2	Laboratory Equipment Required for Chemical and Physical Soil Routine Analysis	141
3	Equipment and Supplies Required for Cereal Breeding (Barley & Wheat) and Field Variety Testing for the Central Tunisia Project Area	143
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Appendix Table C-1. Proposed Long-term Staffing Pattern at Le Kef Applied Field Crops Training and Research Institute--to Serve the Central Tunisia Rural Development Project Area.

Position Description	Level of Training	
	Minimum	Desired
1. Cereal Breeder - Barley	MS	PhD
2. Cereal Breeder - Wheat	MS	PhD
3. Plant Pathologist (Cereals)	MS	PhD
4. Soil Scientist (Fertility, Management, Soil Analysis Laboratory)	MS	PhD
5. Crop Production Agronomist (Dryland)	MS	PhD
6. Farm Management Economist	MS	PhD
7. Weed Control Specialist	B S.	MS
8. Farm Machinery and Experiment Station Management Spcialist	B.S	MS
9. Horticulturist (Production and Marketing of Fruit, Nuts and Vegetables)	MS	PhD
10. Irrigation and Conservation Engineer	B.S.	MS
11. Extension Training Specialist	B.S.	MS

Note: This staffing pattern was proposed by the present director of the Le Kef Training Institute, Dr. Daaloul, and assumes that in the future this facility will become an integrated, applied training and research center serving the agricultural needs of the Central Tunisian region.

Appendix Table C-2. Laboratory Equipment for Chemical & Physical Soil Routine Analysis for the Le Kef Research and Training Institute.

1. pH meter with glass electrode.
2. Centrifuges for 12 ml and 50 ml conical tubes.
3. Photoelectric colorimeter.
4. Flame photometer with burner.
5. Drying oven.
6. Muffle furnance with automatic temperature control.
7. Vacuum dessicators (with porcelaine plates).
8. Two Khjedal sets (four places each).
9. Conductivity set apparatus (Bridge scale and cell).
10. Reciprocating shaker.
11. Motored stirrer, blender and a mixer.
12. Automatic pipet distribution set.
13. Automatic cleaning sets for pipet and for ph meter set.
14. Distilled water Alambic set.
15. Thermometer 200°C.
16. Balances (Quick readings - accurate 0.1 gm - o.ol gm).
17. Containers, funnels, flasks (all kinds), test tubes, beakers, pyrex bottles, filter funnels, etc.
18. Pressure plate extractor (110 - 1/3 atm) with accessories.
19. Pressure-membrane or ceramic plate extractor (15 atm) with accessories.
20. Volumetric pressure extractor (for hysteris studies).
21. Compressor to provide pressure needed for the extractor.
22. Pressure control manifolds and components (valves, adapter, fittings, etc.)

Appendix Table C-2 cont.

23. Cans with watertight lids for moisture sampling.

24. Rings & rubber rings (to order with the extractor).

25. Sets of sieves = openings = 2, 1 & 0.5 mm round hole
= 60 mesh.
= 80 mesh.
=140 mesh.
=300 mesh.

26. Pycnometers.

27. Dispersion apparatus with igh speed stirring motor.

28. Wet sieving apparatus.

29. Soil permeability and soil hydraulic conductivity apparatus.

30. Modolus of Rupture apparatus.

31. Soil sampling tubes, or soil auger of different sizes and drop hammer.

32. Chemical reagents for standard soil analyses.

33. Spare parts for all of the above equipment.

34. Two electronic calculators, desk model, printing, programable.

35. Office copy machine for forms and reports.

Appendix Table C-3. Equipment and Supplies Required for Cereal Breeding (Barley & Wheat) and Field Variety Testing for the Central Tunisia Project Area.

A. Equipment Transport:

1. Heavy-duty, (3/4 to 1 ton) 4-wheel drive, crew-cab, picking truck capable of towing 6-ton equipment trailer. Equipped with electric brake, tail, stop, and signal light outlets for trailer;

2. Six (6) ton, low-boy, equipment trailer equipped with electric brakes and all legal stop, tail and signal lights, 10-ton capacity winch with 100 foot cable for loading non-powered field equipment.

B. Field Equipment for variety testing (seedbed preparation):

1. 50-70 horse power tractor with 3-point and drawbar hitch attachments,remote hydraulic controls (2); complete sets of front-end and rear wheel weights to maximum capacity;

2. Disk harrow 6-8 ft. 3-point attached;

3. Sweep cultivator 7-8 ft. with tine harrow attachment, 3-point attached;

4. Spring-tooth harrow 7-8 ft., 3-point attached;

5. Spike tooth, lever adjustable harrow, 7-8 ft., 3-point attached.

C. Plot Seeding and Harvesting Equipment (variety testing):

1. Self-propelled, 6-10 row, core type plot seeder equipped with double disk openers and press wheels. (Available from F. Walter Wintersteiger Company, Austria). Accessory equipment should include seed distributor heads of 2, 3, 4, 5, 6, 8, and 10 outlets for various row spacing trials. (Note: This equipment is used in cereal breeding and variety testing programs throughout the world in many LDC's. Most CIMMYT cereal programs use this plot seeder.)

2. Self propelled plot combine. 4-5 foot (140 cm) "HEGE Type". Available from Germany. (Note: This plot combine is used e tensively tin CIMMYT, Ford and Rockefeller Foundations, International Research Centers and FAO Programs in LDC programs throughout the World).

Appendix Table C-3 cont.

3. Field Scales and Balances:

   a. 1000 gm (1 kg) to 50 kg. for large field plots;
   b. 1 gm to 2000 gm for small field plots;
   c. .01 to 1000 gm for small seed or head smaples.

4. Seed Cleaning Equipment 500 gm to 50 kg capacity;

5. Grain test weight apparatus (metric);

6. Portable Generator - 5000 watts 110-220 volts for power source to operate vacumn cleaner and power tools for repair;

7. Vacumn cleaner - 5 gallon capacity - heavy duty for cleaning seeding and harvesting equipment to prevent seed mextures;

8. Field measuring tapes stainless steel (metric) 2-50 meter and 2-100 meter sizes in carrying case;

9. Garden wheel hoe for marking plot boundaries during planting. (U. S. type recommended);

D. Cereal -Breeding Equipment (Barley and Wheat):

1. Individual plant threshers (6 needed);
2. Stationary plot threshers (Vogel type - 4 needed);
3. Individual head or spike thresher (4 needed);
4. Two-row plot binder (Japanese rice finder) (2 needed);
5. Barley de-owners (3 needed);
6. Electronic seed counter (1 needed);
7. Desk calculator-printing, programable type for statistical analyzer (2 needed).

E. Cereal Quality Laboratory Equipment (Barley and Wheat):

1. Protein Analyzer apparatus;
2. Miscellaneous Cereal laboratory equipment

Appendix Table C-4. List of Equipment Required for Mobile Units to Conduct Soil Fertility and Agronomic Field Trials on Dryland Cereals in the Central Tunisia Project Area.

A. Transport Equipment:

1. Heavy Duty (3/4 - 1 ton), 4-wheel drive, pick-up truck. Capable of and equipped to, tow 6-ton equipment trailer;

2. Six-ton capacity 10-boy equipment trailer completely equipped with signal lights and electric brakes; and 10-ton capacity winch for loading field equipment.

B. Tillage Equipment:

1. 50-70 horsepower Tractor, equipped with 3-point and drawbar hitches, remote hydraulic valves (2 sets), complete sets of front end and rear wheel weights to maximum capacity;

2. Moldboard plow, compatible to and within horsepower range of the above tractor. Equipped with smoothing harrow;

3. Offset disk plow (24 to 26 inch disks) 3-point attached and compatible with and in horsepower range of the above tractor;

4. Sweep-chisel plow combination - 3 point attached equipped with both sweep and chisel points, springloaded tine harrow, compatible with and in horsepower range of the above tractor;

5. Spring-tooth harrow, 3-point attached - 8-foot (2,45m) compatible with above tractor;

6. Spike-tooth harrow - 3-point attached - 3-4 foot sections, lever adjustable.

C. Planting and Fertilizing Equipment:

1. Grain drill, 8-foot (2.45m) double disk type openers, 8-inch spacing, gang press wheels, 3-point or drawbar attached with fertilizer box attachment;

2. Grain drill, 8-foot (2.45 m) shovel type openers, 12-inch spacings, 3-inch steel press wheels, with fertilizer box attachment, single drawbar attachment;

3. Fertilizer spreader, 8-foot - positive-feed type, 3-point attached (Barber fertilizer spreader type).

Appendix C-4 cont.

D. Harvesting Equipment:

1. Plot combine harvester 4-5 ft. (140 cm) Hege-type (manufactured in Germany).

E. Pest Control Equipment:

1. Plot Sprayer, 24-foot, equipped with 3 separate spray booms each individually operated by multiple control valve. 50-gallon capacity - stainless steel of fiber glass lined tank; complete with gasoline engine, pump, pressure regulator valve, spray nozzles and tips mounted on small trailer.

2. Plot Sprayer - 10 foot - bicycle-type with air pressure tank - complete with tanks, boom, spray nozzles, spray tips, pressure regulator and all plumbing hardware.

F. Soil Sampling Equipment:

1. Hydraulic powered soil sampler. Self-contained unit complete with engine (18 hp.),tool box, rotary attachment, mounted on two-wheeled trailer equipped with tail, stop and signal lights. (Manufactured by Giddings Co., Fort Collins, Colorado, U.S.A.)

2. Accessories for hydraulic soil sampler:

a) main cylinder with 60-inch (150 cm) stroke
b) 1 5/8" flight auger, pin-type adapter
c) 2" flight auger, pin-type adapter
d) 2-1 5/8" sampling tubes - 60" (150 cm) split sides-pin-type adapter
e) 2-2" sampling tubes - 60" (150 cm) split sides-pin-type adapter
f) 1-1 5/8" steel cleaning brush
g) 1-2" steel cleaning brush
h) 10 - 1 5/8" soil bits (5 regular + 5 quick release type)
i) 10 - 2" soil bits (5 regular + 5 quick release type)
j) Pipe vise - mounted on trailer.

G. Miscellaneous Field Research Equipment:

1. Portable air compressor - field air source for cleaning combine during harvesting for pure seed source, air source for bicycle plot sprayers, air source for tire pressure and tire repair.

Appendix C-4 cont.

2. Portable generator - 5000 watt - 120-220 volts for field repair using arc welder and/or electric drill; also for vacumn cleaner for cleaning grain drills and combine harvester during planing and harvesting.

3. Field scales and balances:

   a) 1 to 50 kg. capacity for large field plots;
   b) 1 to 200 gram capacity for small plot samples;
   c) .01 gram to 1000 gram (mettler type) for weighing soil samples and small grain samples.

4. Field measuring tapes (metric) stainless steel 2-50 meter and 2-100 meter tapes.

Appendix Table C-5. Calendarized Summary of Preliminary Cost Estimates for Academic Participant Training for USAID Dryland Farming Intervention for Central Tunisia

Item	Amounts Needed by Years							
	1979		1980		1981		3-Year Total	
	$	TD	$	TD	$	TD	$	TD
A. 4 M.S. Trainees (24 MM each)	52,800	22,000	61,680	25,700	--	--	114,480	47,700
B. 1 M.S. Trainee (30 MM each)	13,200	5,500	15,420	6,425	8,250	3,438	36,870	15,363
C. 2 PhD Trainees (36 MM each)	26,400	11,000	74,016	30,840	33,000	13,750	133,416	55,590
Totals	92,400	38,500	151,116	62,965	41,251	17,188	284,767	118,653

Appendix Table C-6. Calendarized Summary of Preliminary Cost Estimates for Short-term Participant Training for the USAID Dryland Farming Intervention for Central Tunisia

Item	Amounts Needed By Years							
	1979		1980		1981		3-Year Total	
	$	TD	$	TD	$	TD	$	TD
1. Soil Fertility Specialist (2 MM)	4,200	1,750	--	--	--	--	4,200	1,750
2. Farm Management Specialist (3 MM)	6,300	2,625	--	--	--	--	6,300	2,625
3. 4 Agronomist from Project Area (1 MM each)	8,400	3,500	--	--	--	--	8,400	3,500
4. 1 Weed Control Specialist (3 MM)	--	--	7,050	2,938	--	--	7,050	2,938
5. 1 Farm Machinery Specialist (3 MM)	--	--	7,050	2,938	--	--	7,050	2,938
6. 1 Extension Training Specialist (3 MM)	--	--	7,050	2,938	--	--	7,050	2,938
7. 1 Irrigation & Conservation Specialist (3 MM)	--	--	7,050	2,938	--	--	7,050	2,938
8. 10 Selected Technicians (1 MM each)	--	--	--	--	25,150	10,479	25,150	10,479
Totals	18,900	7,875	28,200	11,750	25,150	10,479	72,250	30,104

Appendix Table G-7. Calendarized Summary of Preliminary Cost Estimates for Proposed USAID Short-term Consultants for the Dryland Farming Intervention for Central Tunisia

Item	Amounts Needed by Years 1979			1980			1981			3-Year Total		
	MM	$	TD	MM	$	TD	MM	$	TD	MM	$	TD
1. Crop Production Agronomist (Dryland)	6	66,000	27,500	3	33,000	13,750	1	11,000	4,583	10	110,000	45,833
2. Soil Fertility (Laboratory Specialst)	5	55,000	22,917	3	33,000	13,750	2	22,000	9,167	10	110,000	45,833
3. Farm Machinery/Exper. Station Management	5	55,000	22,917	3	33,000	13,750	2	22,000	9,167	10	110,000	45,833
4. Farm Management Economist	2	22,000	9,167	3	33,000	13,750	1	11,000	4,583	6	66,000	27,500
5. Weed Control Specialist	3	33,000	13,750	2	22,000	9,167	1	11,000	4,583	6	66,000	27,500
6. Irrigation and Conservation Specialist	2	22,000	9,167	2	22,000	9,167	2	22,000	9,167	6	66,000	27,500
7. Extension Training Specialist	2	22,000	9,167	2	22,000	9,167	2	22,000	9,167	6	66,000	27,500
Totals	25	275,000	114,58	18	198,000	82,500	11	121,000	50,417	54	594,000	247,500

Appendix Table C-8. Calendarized Summary of Preliminary Cost Estimates for All Proposed USAID Interventions in Dryland Crop Production (Cereals - Barley & Wheat) in Central Tunisia

Item	Amounts Recommended by Years							
	1979		1980		1981		3-Year Totals	
	$	TD	$	TD	$	TD	$	TD
A. Equipment:								
(1) Soil Analysis Laboratory (Appendix Table C-2)	90,000	37,500	--	--	--	--	90,000	37,500
(2) Cereal Variety Testing & Breeding (Append. Table C-3) - Mobile Field Research Units (2)	200,000	83,333	--	--	--	--	200,000	83,333
(3) Soil Fertility & Agronomy (Append. Table C-4) - Mobile Field Research Units (2)	240,000	100,000	--	--	--	--	240,000	100,000
Sub-Totals	530,000	220,833	--	--	--	--	530,000	220,833
B. Short-Term Participant Training: (Append. Table C-6)	18,900	7,875	28,200	11,750	25,150	10,479	72,250	30,104
C. USAID Short-Term Consultants (Append Table C-7)	275,000	114,585	198,000	82,500	121,000	50,417	594,000	247,500
D. Operating Funds (Fuel, Repairs, etc.)	64,600	26,917	72,00	30,000	96,000	40,000	232,600	96,917
E. Senior Technical Advisor (36-Month Total; 1/2 yr. 1; 1/2 yr.2)	119,500	49,792	112,500	46,875	--	--	232,000	96,667
Sub-Totals (A + B + C + L + E)	1,008,000	420,000	410,700	171,125	242,150	100,896	1,660,850	692,021
F.* Participant Training (Academic) (Append. Table C-5)	92,400	38,500	151,116	62,965	41,251	17,188	284,767	118,653

*This item probably will be funded under the Agricultural Technology Transfer Project.

APPENDIX SECTION D

Sample Forms for Developing Enterprise Budgets

Budget Form No.	Title	Page No.
4	Oats/Vetch Hay	153
11	Barley Grain (Dryland)	154
24	Tomatoes	155
26	Almonds	156
30	Sheep	157

*Budget No. 4 - Crop Enterprise Budget - OATS/VETCH HAY

Central Tunisia Area: Delegation Djilma Sector _____

Kind of Crop Oats/Vetch Hay Dryland ( ); Irrigated (XX)

Description Grown on irrigated land; excellent management

1. Yield: 40 bales (1320k) per hectare	D	1,320kg
2. Price, Dinars per kilo hay	D	40
3. GROSS INCOME per hectare	D	211.2
4. VARIABLE COSTS PER HECTARE:		
5. Land preparation costs	D	12
6. Fertilizer & Lime. Nitrogen, Phosphate, Potash (m)		24
7. Seed		16
8. Crop Chemicals & Supplies		
9. Custom machine hire. Harvesting		13 to 15
10. Machinery: fuel, repairs, etc.		
11. Feed & Supplies for draft animals.		
12. Miscellaneous Costs. Manure		5
13. Other. Water		10
14. TOTAL VARIABLE COSTS (cal. 5-13)	D	82
15. GROSS MARGIN PER HECTARE (L. 3-L.14)	D	129.2
16. Days Man Labor needed/ha		
17. Hours draft animals work/ha.		

*FAO yields & inputs from Djilma Delegation; price data from CNEA.
(Budget prepared by Monia Bouratbine, CNEA.)

*Budget No. 11 - Crop Enterprise Budget - BARLEY (Dryland)

Central Tunisia Area: Delegation Sbiba Sector _____

Kind of Crop Barley Dryland (XX); Irrigated ( )

Description	Improved	Present
1. Yield: Quintals per hectare	8	D 4
2. Price, Dinars per Quintal	4	D 4.000
3. GROSS INCOME per hectare	32,000	D 16.000
4. VARIABLE COSTS PER HECTARE:		
5. Land preparation costs		D _____
6. Fertilizer** 80 KG/HA = D 4.800/ha	3.700	0
7. Seed 70 Kg x 5500 the quintal	4,800	3.850
8. Crop Chemicals & Supplies		_____
9. Custom machine hire. 3 h x 2000 + 4.000 threshing	10.000	10.000
10. Machinery: fuel, repairs, etc.		_____
11. Feed & Supplies for draft animals		_____
12. Miscellaneous Costs		_____
13. Other. 5 working man-days x 1.200		6.000
14. TOTAL VARIABLE COSTS (cal. 5-13)	18,500	D 9.850
15. GROSS MARGIN PER HECTARE (L. 3-L.14)	13,500	D 6.150
16. Days Man Labor needed/ha	10 days	5 days
17. Hours draft animals work/ha		_____

*Budget Data for Central Tunisia Project Area; from CRDA (Commisariat Regional de Development Agricole). (Prepared by Tahar Ben Salem.)

**50 kgs. N/ha @ D 0.038 = D 1.900
50 kgs. P_2O_5/ha @ D 0.036 + D 1.800
D 3.700 (Rates used at Ousseltia station)

*Budget No. 24 - Vegetable Budget - TOMATOES

Central Tunisia Area: Delegation Sbiba Sector _____

Kind of Crop Tomatoes (in season) Dryland ( ); Irrigated (x)

Description _____

1. Yield: tons per hectare		20
2. Price, Dinars per ton	D	36.000
3. GROSS INCOME per hectare	D	720.000
4. VARIABLE COSTS PER HECTARE:		
5. Land preparation costs	D	
6. Fertilizer & Lime. (2Q/ha amon. nitrate)+(2.5Q/ha Super Phosphate)+(2Q/ha potash)+(84.000 manure)		
7. Seed 15,000 plants x 3 millimes		45.000
8. Crop Chemicals & Supplies Sulfur 75 kg. x 0.115+ Detane		9.000
9. Custom machine hire		
10. Machinery: fuel, repairs, etc.		
11. Feed & Supplies for draft animals		
12. Miscellaneous Costs. 100 working man-days x 1.500		150.000
13. Other. Water for irrigation 8000^{m3} x 4		32.000
14. TOTAL VARIABLE COSTS (cal. 5-13)	D	348.5000
15. GROSS MARGIN PER HECTARE (L. 3-L.14)	D	371.500
16. Days Man Labor needed/ha		
17. Hours draft animals work/ha		

*Budget Data for Central Tunisia Project Area; from CRDA (Commisariat Regional de Development Agricole). (Prepared by Tahar Ben Salem.)

*Budget No. 26 - Tree Crop Budget - ALMONDS

Central Tunisia Area: Delegation Sbiba Sector _____

Kind of Crop Almonds Dryland (x); Irrigated ( )

Description _____

1. Yield: kg. per hectare		100
2. Price, Dinars per kg.	D	0.350
3. GROSS INCOME per hectare	D	35.000
4. VARIABLE COSTS PER HECTARE:		
5. Land preparation costs	D	
6. Fertilizer & Lime		
7. Seed		
8. Crop Chemicals & Supplies		1.000
9. Custom machine hire. 6 hrs. x 2.000		12.000
10. Machinery: fuel, repairs, etc.		
11. Feed & Supplies for draft animals		
12. Misc llaneous Costs. harvesting) hired)labor		1.500
13. Other. pruning) 1/2		6.000
14. TOTAL VARIABLE COSTS (cal. 5-13)	D	20.500
15. GROSS MARGIN PER HECTARE (L. 3-L.14)	D	14.500
16. Days Man Labor needed/ha 5 days		5
17. Hours draft animals work/ha		

*Budget Data for Central Tunisia Project Area; from CRDA (Commisariat Regional de Development Agricole). (Prepared by Tahar Ben Salem.)

**Budget No. 30 - Livestock Budget - SHEEP

Kind of Livestock Enterprise SHEEP ENTERPRISE

1. Description of Sales from Enterprise (from One Unit):*

Wool - 2'1/2 kg. x 0.740 TD/kg.	1.850 TD
Lambs - male - 24 kg. x .35 = 8.4 kg. x 0.750 TD/kg.	6.300 TD
female 25 kg. x .14 = 3.5 kg. x 0.650 TD/kg.	2.275 TD
Cull Ewes - 38 kg. x .20 = 7.6 kg. x 0.450 TD/kg.	3.420 TD

**2. GROSS RECEIPTS per Unit (dinars). . . . . D 13,845 TD

3. Cost of feed per Unit (dinars) + milk & manure income .02 TD

TOTAL 14.0 TD

a. Pasture . . . . . D _____

b. Other feed. Concentrate . . . . . D 0.800
(20 kg. x 40 m.)

4. Medicine. . . . . D 0.150

5. Misc. . . . . D 0.050

6. Other . . . Marketing . . . . . D 0.280

7. Other . . . Selling tax . . . . . D 0.050

**8. TOTAL VARIABLE COST per Unit. . . D 1.330

9. GROSS MARGIN per Unit (L.2 - L.8) D 12.67 (13.0 rounded)

10. Hours Man Labor Required per Unit 5 (estimated)

11. Investment Required per Unit. . . D 20 (estimated)

*One unit includes one ewe, lamb and portion of replacement for flock. The budget assumes a 5-year productive life/ewe --selling of .2 ewe per year and savings % of ewe lambs for replacement.

**Data received from CNEA (from Philippe Ardounin-Dumazet and Hafi Chedli)

APPENDIX SECTION E

Sample Procedures for Evaluating Farming Systems

Form No.	Title	Page No.
TU-1	Capital Investment Summary	159
TU-2	Land Use System	160
TU-3	Livestock System	161
TU-4	Profitability Analysis	162
TU-5	Economic Feasibility (Cash-Flow) Analysis	163

CENTRAL TUNISIA RURAL DEVELOPMENT PROJECT

Evaluation of Model Farming Systems

Form TU-1

CAPITAL INVESTMENT SUMMARY

Present System ( ) or Improved System No. A

DESCRIPTION OF SYSTEM:

Kind of Land -

Crop & Livestock Enterprises -

A. LAND INVESTMENT: 30 ha x 100 TD/ha ..... TD 3,000

B. FARM BUILDINGS:

1. Storage Bldg's..... TD 25
2. Corral..... TD 10
3. Other..... TD

4. Total bldg. Investments..... TD 35

C. TOOLS & EQUPMENTS:

1. Hand Tools..... TD 5
2. Field Equipment..... TD 20
3. Transport.Equipment..... TD 20
4. ..... TD

5. Total Equipment Investment..... TD 45

D. BREEDING ANIMALS:

1. Sheep.....No. (15 ewes, 1 ram) x TD 20 /head..... TD 320
2. Goats.....No. ____ x TD ____ /head..... TD
3. Cattle....No. ____ x TD ____ /head..... TD

4. Total Breeding Animal Investment..... TD 320

E. WORK ANIMALS:

1. Donkeys...No. 2 x TD 25 /head..... TD 50
2. Mules.....No. ____ x TD ____ /head..... TD
3. Horses....No. ____ x TD ____ /head..... TD
4. Camels....No. 1 x TD 250 /head..... TD 250

5. Total Work Animal Investments..... TD 300

F. TOTAL INVESTMENT CAPITAL: ..... TD 3,700

Form TU-2

CENTRAL TUNISIA RURAL DEVELOPMENT PROJECT

Evaluation of Model Farming Systems

LAND USE SYSTEM

Kind of System: Present ( ) or Improved System No. A

Land Use*	Season In	Season Out	**No. of Hectares	Yield ___/ha.	Total Product	***Gross Margin Per ha.	***Gross Margin Total	Days Labor*** Per ha.	Days Labor*** Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1 Barley (Improved)	--	--	8	8 Ql/ha.	64 Ql.	13.5	108	10	80
2 Almonds	--	--	2	100 Kg/ha.	200 Kg.	14.5	29	5	10
3 Rotation Pasture	--	--	10	(Production & Income from Sheep Enterprise)				2	20
4 Non-Rotation Pasture	--	--	8	(Production & Income from Sheep Enterprise)				--	--
5									
6									
7									
8									
9									
10									
11									
12									
13 Waste Land	xx	xx	2	xxxx	xxxx	xxx	xxx	xxx	xxx
14 TOTALS	xx	xx		xxxx	xxxx	xxx	137	xxx	110

* Includes cereal crops, forage crops, pastures, vegetables, fruits & nuts, fallow, & waste land.

** In case of double or multiple cropping, circle (ha) for succeeding crops and omit from total.

*** Gross Margins and Total Days Labor should be transferred directly from individual budgets.

CENTRAL TUNISIA RURAL DEVELOPMENT PROJECT

Evaluation of Model Farming Systems

Form TU-3

LIVESTOCK SYSTEM

Kind of System: Present ( ); Improved No. A

Kind of Enterprise	No of Units*	Gross Margin**		Days Labor Used***	
		TD/Unit	TD Total	Per Unit	Total
(1)	(2)	(3)	(4)	(5)	(6)
1. Sheep (15 ewes, 1 ram)	15	13	195	5	75
2.					
3.					
4.					
5.					
6.					
7. TOTALS FOR SYSTEM	xxxx	xxxx	195	xxxx	75

Units refer to the breeding unit or no. of head as described in Enterprise Budgets.

* Gross Margins and Days Labor Used may be taken directly from the Enterprise Budgets already prepared.

CENTRAL TUNISIA RURAL DEVELOPMENT PROJECT

Economic Evaluation of Model Farming Systems

Form TU-4 PROFITABILITY ANALYSIS

Kind of System: Present ( ); Improved No. A

Line	Item	Details	Total
	(1)	(2)	(3)
1.	TOTAL INVESTMENT CAPITAL (Form TU-1, Line F)	TD	TD 3,700
	LABOR--		
2.	Crop Labor Days (Form TU-2, Col. 10)	TD 110	
3.	Livestock Labor Days (Form TU-3, Col. 6) . .	TD 75	
4.	Miscellaneous Farm Labor (Est. days)	TD 10	
5.	Total Days Farm Labor.	xxxx	TD 195
	GROSS MARGIN--		
6.	From Cropping System (Form TU-2, Col. 8) . .	TD 137	
7.	From Livestock System (Form TU-3, Col. 4) .	TD 195	
8.	Total.	xxxx	TD 332
	OTHER CASH COSTS--		
9.	Hired Labor: (a) 0 days X (b) 2.0TD/day . .	TD --	
10.	Cash Rent.	TD --	
11.	Rent in Kind: Cash Value.	TD --	
12.	Misc. Expense: 2% of Line 8	TD 6.6	
13.	Other.	TD .4	
14.	Total Other Cash Costs	xxxx	TD 7
15.	NET CASH FARM INCOME (Line 8-Line 14) . . .	xxxx	TD 325
16.	DEPRECIATION ALLOWANCE: Equip. & Buildings	xxxx	TD 5
17.	Cash Income above Depreciation (Line 15-16)	xxxx	TD 320
18.	Cash Value Farm-Produced Family Food (est.)	xxxx	TD 275
19.	FARM PROFIT (Line 17 + Line 18).	xxxx	TD 595
20.	Return to Family Labor & Mgt. [L.19-(L.1 X 6 %)].	xxxx	TD 373
21.	Return per Day [L.20÷(L.5-L.9a)]	xxxx	TD 1.91
22.	Return to Capital [L.19-(L.5-L.9a X L.9b)] .	xxxx	TD 205
23.	% Return to Capital (L.22÷L.1 X 100)	xxxx	% 5.54

CENTRAL TUNISIA RURAL DEVELOPMENT PROJECT

Economic Evaluation of Model Farming Systems

ECONOMIC FEASIBILITY (CASH-FLOW) ANALYSIS

Kind of System: Present ( ); Improved No. A

	Item	Details	Total
	(1)	(2)	(3)
1	Net Cash Farm Income (Form TU-4, L.15).	TD 325	
2	Cash Rent Received.	TD --	
3	Wages from off-farm work.	TD 57	
4	Other Cash Family Income.	TD --	
5	TOTAL CASH FAMILY INCOME.	xxxxx	TD 382
	CASH FAMILY EXPENSES:	xxxxx	
6	Family Clothing	TD 20	
7	Family Food	TD 100	
8	Weddings, Religious Ceremonies, etc. .	TD 50	
9	Interest paid in Cash	TD 10	
10	Other Cash Family Expenses.	TD 20	
11	TOTAL CASH FAMILY EXPENSES.	xxxx	TD 200
12	*NET CASH FAMILY INCOME (L.5-L.11). . .	xxxx	TD 182

*Cash available for savings, debt payments, and new investments.

APPENDIX SECTION F

Copy of USAID/University of Missouri
Contractual Assignment

Pages 165-170

UNITED STATES OF AMERICA
AGENCY FOR INTERNATIONAL DEVELOPMENT

MAY 31 RECD

1. Country of performance TUNISIA

2. Mark one and insert appropriate numbers:
☒ Indefinite Quantity Contract No. AID/afr-C-1139, Work Order No. 6
☐ Requirements Contract No. _____, Delivery Order No. _____
☐ Basic Ordering Agreement No. _____, Task Order No. _____

NEGOTIATED PURSUANT TO THE FOREIGN ASSISTANCE ACT OF 1961, AS AMENDED, AND EXECUTIVE ORDER 11223

3. CONTRACTOR (Name and Address): The Curators of the University of Missouri 215 University Hall Columbia, Missouri 65201	4. CONTRACTING OFFICE (Name and Address): Agency for International Development Office of Contract Management Services Operations Division Washington, D.C. 20523
5. PROJECT OFFICE (Name and Address): Mr. T. Wilson, NE/TECH/AD	6. SUBMIT VOUCHERS TO (Office Name and Address): Office of Financial Management (SER/FM/PAD) Agency for International Development Washington, D.C. 20523
7. EFFECTIVE DATE: See ARTICLE V	8. ESTIMATED COMPLETION DATE: September 1, 1978

9. ACCOUNTING AND APPROPRIATION DATA (Insert appropriate numbers):

Amount Obligated: $32,333 FIO/T No.: 298-035-3-6287005 (A-1)

Appropriation No. 72-1181021.3 Allotment No.: 843-62-298-00-69-81

10. The United States of America, represented by the Contracting Officer signing this Order, and the Contractor agree that: (a) this Order is issued pursuant to the Contract or Agreement specified in Block 2 above and (b) the entire Contract between the parties hereto consist of this Order and the Contract or Agreement specified in Block 2 above.

11a. NAME OF CONTRACTOR: Curators of the University of Missouri	11b. UNITED STATES OF AMERICA AGENCY FOR INTERNATIONAL DEVELOPMENT
BY (Signature of authorized individual): Sandra F. Mady	BY (Signature of Contracting Officer):
TYPED OR PRINTED NAME: Sandra F. Mady	TYPED OR PRINTED NAME: F. J. Moncada
TITLE: Assistant to President	TITLE: CONTRACTING OFFICER
DATE: May 19, 1978	DATE:

Temp. Form (1/78)

ARTICLE I - OBJECTIVE

1. To complete a descriptive plan for the specific interventions selected from those proposed in the UMC report; and

2. To furnish on-the-spot expertise and reports, to USAID/GOT, to accomplish incorporating the technical interventions into the design of the project. Selected interventions to increase production and raise farm family incomes:

a. Pilot, method/result, demonstrations 1.) deep and shallow water well development for small scale irrigation; and 2.) rain water management and erosion control using terracing, collection, and spreading techniques; and

b. Assess and develop technical assistance requirements and plans aimed at increasing barley production in the project area.

ARTICLE II - SCOPE OF WORK

A. All Consultants:

Literature Review - Make a studied review of the UMC report and biobliography and other information collected and assembled by the USAID/GOT.

In-Country Travel - It will be necessary for the consultants to take "second-looks" in the project area in order to properly orient and correlate plans within the various delegation and secteur administrations.

Consultations - Coordination and consultations with the various GOT agencies is essential to planning.

B. Agricultural Economist - Will be responsible for coordinating all effort including the coordination and completion of reports. He must work with each individual consultant to fill in the various cost sections of each report.

C. Agriculture Economists and Agriculture Engineers - Must review, consult and produce reports as follows:

a. Reports and documentation on phreatic aquifers which have been studied by Tunisian and/or FAO water engineers, Foussana and Thala are examples;

b. Copies of all available theses, reports, studies, plans, etc., involving the Central Tunisian project area;

c. Reports showing potential for additional wells are particularly important in preparing dollar estimates for small irrigation interventions;

d. Reports listing existing wells which are being used, and are available from each of the delegations. These reports are necessary so that needs for pump sets can be quickly determined and estimates of needs for land preparation for irrigation may be made;

e. The detailed records of deep wells which have been drilled and capped, including pumping test data, are available from various sources;

f. The DRES offices may have specifications already drawn for pumps and power units which would expedite purchase orders as well as assisting in making determinations on distributions of natural resources to farm families.

Additional Reports - Must be prepared with rough maps showing specific areas selected for shallow and deep well construction and/or improvement. Maps to include and or identify means for compiling or filling in information gaps, such as:

a. Aquifer information

b. Drilling 'logs'

c. Quality checks

e. Soil maps

f. Meteorological information

g. Construction costs (pumps, digging, linnings, etc.)

h. Operation costs (power, labor)

i. Maintenance problems

j. On-Farm water management problems (salinity)

k. Land distribution problems

Consultations

a. DRES

b. SCS (Soil Conservation)

c. Forestry

d. Delegation and Secteur Administrations

e. Agriculture Research and Agriculture Extension

f. Etc.

D. Barley Agronomist

1. Consultations - Must consult with scientists and technicians in a review of barley research, production and extension efforts including a determination and review of linkages with International Centers for arid lands

agriculture. Following is a list of consultations to be made:

a. USAID/Tunis

b. Ministry of Agriculture (as required)

c. Institute for National Research in Agriculture and Technology (INRAT)

d. Research Station personnel dealing with Barley Research

e. Extension Service personnel dealing with Barley production

f. Dr. Georges Novikoff, Resident Scientific Coordinator, Tunisian Presaharan Project, Tunis

g. CNEA, and

h. Cereals Institute at LeKef (Dr. Daaloul)

ARTICLE III - REPORTS

In addition to other reports as required each team member departing Tunisia, must provide a descriptive outline covering his specific intervention and leave it with the Mission Director. Within three weeks following departure a final report must be submitted to the Mission Director. Details must include

a. Background statement or 'beginning point' for each intervention, describe the setting for each development, scope of development - including time frames to reach development plateaus, numbers of farmers to be served, etc., introduced technologies to be employed, expected socio-economic changes to be reached and end of project status;

b. Goal statment

c. Purpose statement (quantified)

d. Inputs needed (quantified)

e. Outputs expected (quantified)

f. Analysis of costs and returns per farmer served

g. Analysis of intervention cost effectiveness including alternative scales, Tunisian capacity to use "cookbook designs", Tunisian capacity to absorb intervention and cost/improved Ha.

h. Conditions precedent to implementation

i. Outstanding, unanswered issues and/or assumptions made

j. The final report must include a detailed plan to be followed in implementing the development of each intervention. Details including sequential time frames, agencies and personnel responsibilities, training, materials needed, technical assistance requirements and costs

Completion of French translations to be agreed upon by team leader and Mission Director prior to teams departure.