EWUP TECHNICAL REPORT NO. 38

PRECISION LAND LEVELING ON ABU RAYA FARMS, KAFR EL SHEIKH GOVERNORATE, EGYPT

by

EWUP Kafr El Sheikh Team
As Compiled By
Thomas W. Ley

April 1983

EGYPT WATER USE AND MANAGEMENT PROJECT

22 El Galaa St., Bulak, Cairo, Egypt

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KAFR EL SHEIKH GOVERNORATE
EGYPT

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Prepared under support of

WATER DISTRIBUTION RESEARCH INSTITUTE, WATER RESEARCH CENTER

MINISTRY OF IRRIGATION, GOVERNMENT OF EGYPT

Contracting agencies

Colorado State University
Engineering Research Center
Ft. Collins, Colorado 80521
USA

Consortium for International
Development
5151 E. Broadway, Ste., 1500
Tucson, Arizona 85711 USA

All reported opinions, conclusions or
recommendations are those of the writers
and not those of the supporting or contracting agencies.

ABSTRACT

Three important aspects of the precision land leveling (PLL) work accomplished by the EWUP Kafr El Sheikh Team in Abu Raya are reviewed. These include: 1) qualitative review of the experience in performing PLL in Abu Raya with documentation of the need, the constraints, the procedural and logistical factors involved, manpower requirements, etc., 2) quantitative review of the earthwork volumes, cuts, fills, estimated costs, machinery hours, etc., and 3) review of the impact PLL and a package of other farm irrigation improvement practices has had in farm water management improvement in Abu Raya.

Individual farm fields in Abu Raya were found to have an average ± 6.5 cm elevation deviation (average range of 0.13 m). This is more than four times the recommended tolerance of ± 1.5 cm (0.03 m range) for level basin irrigation, the method used in Abu Raya.

The earthwork volumes (cut and fill volumes) necessary for precision land leveling in Abu Raya were found to be relatively small compared to other areas of the world. Cut volume is used for determining the cost of PLL operations. Generally, the ratio of cut volume to fill volume was kept to a minimum of 1.30 in this work, however, this was not always possible. Mean estimated cut volume for Abu Raya, based on data from several pre-construction field grid surveys, is 59m^3/feddan. This would be the amount required to bring the field to absolute dead level (zero grade in all directions). Due to limitations of machinery, human input and time it is not possible or economically feasible to perform PLL until an absolute dead level field is obtained. The goal of Kafr El Sheikh Team PLL operations for Abu Raya fields was to reach ± 2 cm elevation variation (0.04 m range) on at least 90% of the field. Post-construction field grid surveys were performed on numerous sites to measure the actual cut volume (taken as the difference between the pre- and post- construction grid survey cut volume required to bring the field to absolute dead level). This difference was measured to average 36 m^3/feddan and represents the actual average earthwork cut volume.

Estimates of costs (using EWUP machinery cost tables developed in 1979) are:

LE 22.15/feddan (based on costs for all farm machinery used),
LE 14.10/feddan (based on costs for tractor, scraper and field plane),
LE 0.42/m^3 (based on all farm machinery and pre-construction grid survey cut volume),
LE 0.26/m^3 (based on tractor, scraper and field plane and pre-construction grid survey cut volume).

PLL, improved farm irrigation designs, farm water management advisory assistance to farmers and crop production advice to farmers are main elements of a package which has been implemented on farms in Abu Raya and which consistently has produced irrigation water savings (improved efficiencies), savings of irrigation time and labor and improved crop yields. Water table and soil salinity problems have been effectively alleviated through the program.

68 pages 12 figures 21 tables

مستخلص

قام مشروع تطوير الري بمراجعة ثلاث عوامل هامة متعلقة بموضوع التسوية الدقيقة للأراضي بمنطقة أبوريه في كفر الشيخ وهذه العوامل هي :

(١) مراجعة نوعية خاصة بالكفاءة والخبرة المتوفرة لعمل التسوية الدقيقة للأراضي بالمنطقة وتم كذلك اعداد البيانات الخاصة بالعمالة والاحتياجات اللازمة وطريقة التشغيل والعوائق الموجودة والعوامل المؤثرة ومدى ملائمتها للمنطقة الخ ...

(٢) مراجعة كمية لكميات الحفر والردم والتكاليف اللازمة لساعات التشغيل باستخدام الميكنة الخ ...

(٣) دراسة علاقة التسوية الدقيقة للأراضي بالعوامل الأخرى التي تؤثر على تحسين نظام تطوير الري في منطقة أبوريه .

وقد وجد أن حد الانحراف بمنطقة حقول أبوريه يتراوح مقداره بين ± ٦,٥ سم (في حدود ١٢,٥ متر) ، وهذا يعتبر أكبر من أربع مرات الحد المسموح به للأراضي المستوية والذي يقدر بحوالي ± ١,٥ سم (في حدود ٢٠,٥ متر) وقد وجد أن كميات الحفر والردم بمنطقة أبوريه صغيرة نسبيا بمقارنتها بمناطق أخرى في العالم . ويعتبر حجم الحفر أساسا لتقدير أسعار التكلفة لعمليات التسوية الدقيقة .

وعموما تم الحفاظ على نسبة الحفر إلى الردم إلى أقل ما يمكن وهي ١,٢ مع أن من الصعب الاحتفاظ دائما بهذه النسبة . وقد وجد أن متوسط حجم التسوية اللازمة والمبني على نتائج المسح التقديرية المبدئية هو ٥٩م٣ للفدان وذلك في حالة عمل تسوية دقيقة جدا (تصل إلى ± صفر سم في كل الاتجاهات). ولم يكن باستطاعة الحصول على مثل هذه التسوية نظرا لبعض الصعوبات من ناحية عدم توافر المعدات والوقت والعمال مع عدم جدواها الاقتصادي . وقد كان الهدف مجموعة العمل بكفر الشيخ أن تنجز العمل بدرجة تفاوت تتراوح بين ± ٢ سم (في حدود ٠,٤ متر) وذلك لحوالي ٩٠ ٪ من الحقول على الأقل . وعلى ذلك وجد أن الحجم الفعلي المتوسط اللازم للتسوية (والمبني على نتائج المسح اللازم للحصول على تسوية دقيقة) هو ٣٢٦م٣ / للفدان في المتوسط وذلك لمعظم المناطق .

وقد وجد أن التكاليف التقديرية كالآتي (طبقا لجداول مشروع تطوير الري المستنبطة عام ١٩٧٩ والخاصة باستخدام الماكينة) :

٢٢,١٥ جنيه مصري للفدان (بناء على التكاليف الكلية باستعمال كل الآلات الموجودة)

١٤,١٠ جنيه مصري للفدان (بناء على تكاليف استخدام الجرار والسلاح و وتسوية الحقل)

٠,٤٢ جنيه مصري للمتر المكعب (بناء على التكاليف الكلية باستعمال كل الآلات الموجودة والمسح الأولي اللازم لحجم الحفر والردم)

٠,٢٦ جنيه مصري للمتر المكعب (بناء على تكاليف استخدام الجرار والسلاح

وتسوية الحقل والمسح المبدئي اللازم للحفر والردم)

وقد إتضح أن التسوية الدقيقة للأراضي قد ساعدت على تطوير طرق تصميم الري كما أن توعية وإرشاد الفلاحين ساعد على زيادة الإنتاج المحصولي بأراضيهم ، وقد كان هذا من أهم الإنجازات التي تمت بمنطقة أبوريه والتي ساعدت على توفير كميات مياه الري (وبالتالي تحسين كفاءة الري) ، وكذلك على توفير العمالة والوقت وتحسين المحصول الناتج .

أما عن مشاكل الملوحة وارتفاع منسوب الماء الأرضي فقد قلت حدتها بصورة واضحة خلال فترة البرنامج .

٨٦ صفحة ١٢ شكل ٢١ جدول

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ACKNOWLEDGEMENTS

The authors wish to express their thanks and appreciation for the contributions made to this paper by the staff of the Egypt Water Use and Management Project, and to the field teams at Mansuriya, Kafr El Sheikh and El Minya.

The Project is funded jointly by the Arab Republic of Egypt, and by the United States Agency for International Development. The United States Agency for International Development in Egypt is under the directorship of Mr. Michael P. W. Stone. Mr. John Foster is the United States Agency for International Development Project Officer for the Egypt Water Use and Management Project.

The Egypt Water Use and Management Project is implemented under the auspices of the Ministry of Irrigation's Water Management and Irrigation Technologies Research Institute and in collaboration with both the Ministry of Irrigation and the Ministry of Agriculture through the Soil and Water Research Institute and the Agriculture Ecomomics Institute, which provide the Project with personnel and services.

The Consortium for International Development, with executive offices in Tucson, Arizona, is the United States Agency for International Development Contractor for the Project. American Project personnel are drawn from the faculties of Colorado State University, the lead American university taking part in the Project, Oregon State University, New Mexico State University, and Montana State University. The Project Director is Dr. Hassan Wahby and the Project Technical Director is Dr. Eugene Quenemoen. Dr. E. V. Richardson is the Campus Project Coordinator.

PREFACE

This report is a compilation of precision land leveling (PLL) data and analyses collected and performed by the EWUP Kafr El Sheikh Team. The professional staff is listed on the following page and the contributions of all to the success of the PLL program is acknowledged. Fundamental to the initiation and overall success of the program were Mr. Niel Dimick (formerly with USAID/Cairo), Mr. Ahmed Bayoumi (EWUP), Mr. Shawky Boctor (USAID/Cairo) and Mr. Kern Stutler (TDY engineer from Utah State University who provided significant initial training to the K.S. Staff). The hard work of the K.S. Staff technicians and drivers, particularly Mr. Atia Mostafa Abdo, the tractor driver, contributed in a major proportion to the success of the work accomplished. Also the K.S. professional staff members, Mr. Nehad Ibrahim and Mr. Magdy Awad, who oversaw the farm machinery operation and maintenance is acknowledged.

This report was compiled by Thomas W. Ley. Special thanks are extended to Cheryl Stevens, Diane Maybon and Pam Hobbs for typing various sections of this report.

Kafr El Sheikh Professional Staff

Name	Position*
Samir El Aref	Agronomist & Former Team Leader
Sayed Abdel Hafez	Agronomist
Magdy Awad	Agronomist
Ahmed Ismail	Agronomist
Mahmoud Said	Agronomist
Mohamed Meleha	Agronomist
Tarek Tewfik	Agronomist
Ragy Darwish	Economist
Sobhi Elewa	Economist
Shinawi Abdel Ati	Economist
Yusef Yusef	Economist
Magdy Badawi	Economist
Abdel Fattah Metawie	Engineer & Acting Team Leader
Kamal Ezz El Din	Engineer & Current Team Leader
Saad El Zarka	Engineer & Former Team Leader
Amany El Kayal	Engineer
Sanaa Ezz El Din	Engineer
Ahmed Dardir	Engineer
Saad Hussein Zaki	Engineer
Safaa Fahmy	Engineer
Nehad Ibrahim	Farm Machinery
Abdel Fattah El Masry	Sociologist
Ahmed El Attar	Sociologist
Soheir Kamal Yusef	Sociologist
Nancy Adams	Engineer & Former Ass't. Team Leader
Thomas W. Ley	Engineer & Former Ass't. Team Leader
Kenneth E. Litwiller	Engineer & Current Ass't Team Leader

*as of April 1983

PRECISION LAND LEVELING ON ABU RAYA FARMS
KAFR EL SHEIKH GOVERNORATE, EGYPT

INTRODUCTION

Precision land leveling in Abu Raya was first performed by the Egypt Water Use and Management Project (EWUP) Kafr El Sheikh Team as part of the first field trial conducted during the 1979 Summer season. Figure 1 is a map of part of Egypt showing the EWUP work locations and in particular, the location of Abu Raya and the Kafr El Sheikh Governorate. Figure 2 is a map of Abu Raya district showing irrigation and drainage channels and farms on which EWUP has worked. Collection, analysis and evaluation of precision land leveling data on numerous Abu Raya farms was carried out during successive seasons (as part of other field trials and part of the on-farm water management improvement pilot program in Kafr El Sheikh). The purpose of this work was to study both the technical aspects of the precision land leveling process and feasibility for doing it on farms in the area, and to determine the impact of this practice on improving farm water management in Abu Raya and areas with similar conditions.

The purpose of this report is three-fold. First, the Kafr El-Sheikh Team experience in performing precision land leveling (PLL) is reviewed. Essentially the questions what, where, when, why, how, by and for whom will be answered. From this, conclusions and recommendations to consider for successful development of a PLL program have been formulated. Secondly, the technical details of the PLL work done on Abu Raya farms will be summarized. Included in this are manpower input, machinery input, earthwork volumes and preliminary economic analysis. Finally, the impacts that PLL has had on improving farm water management in Abu Raya will be delineated and summarized.

This report is a compilation and refinement of the available Kafr El Sheikh PLL data. Complete documentation of the results and summaries presented here is available in the Kafr El Sheikh files, and in supporting reports, where the major portion of the available data was reported in a preliminary form. These reports include EWUP Staff Papers #54, 57, and 61; and EWUP Draft Working Papers #75, 86 and 110.

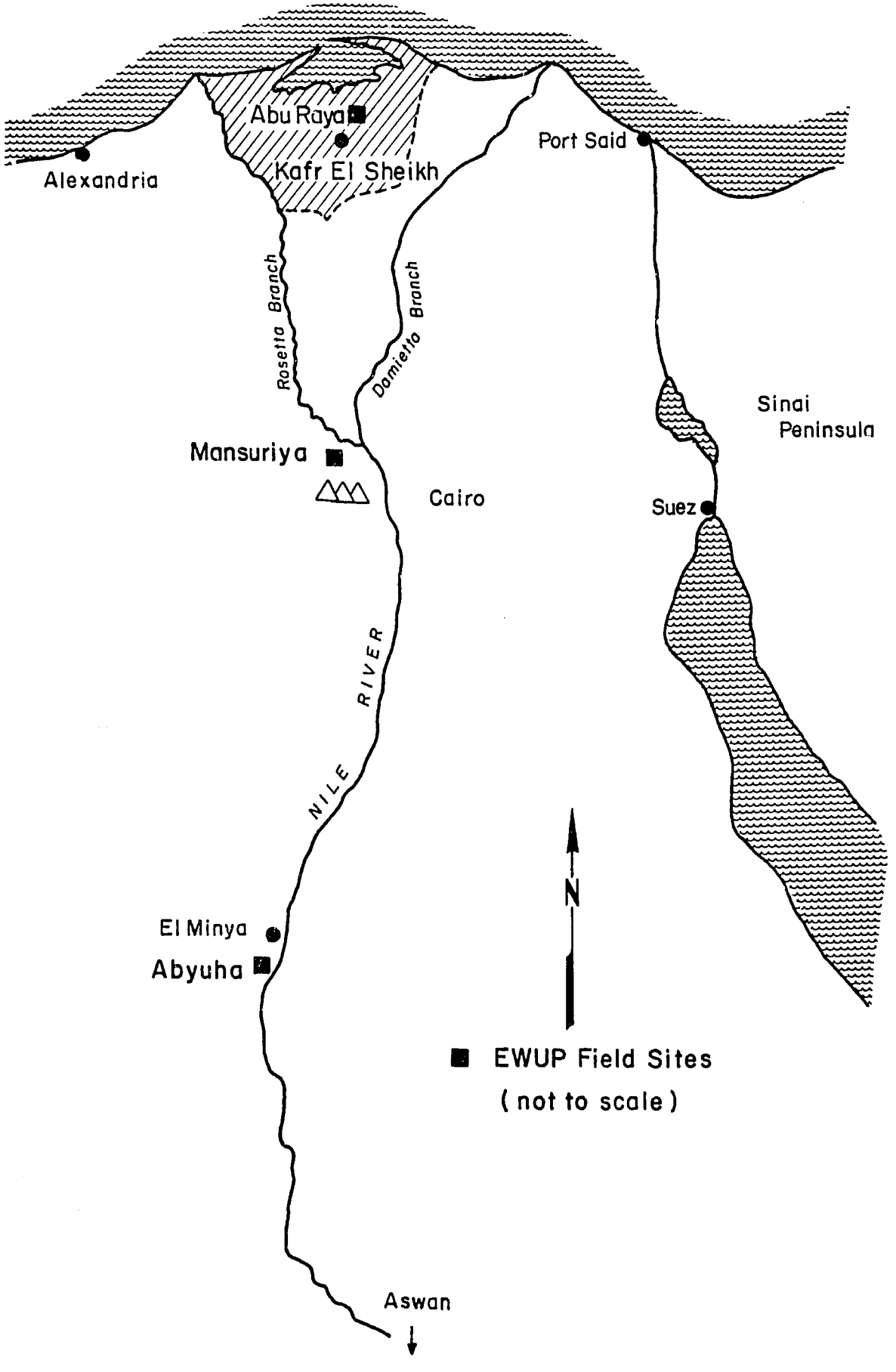
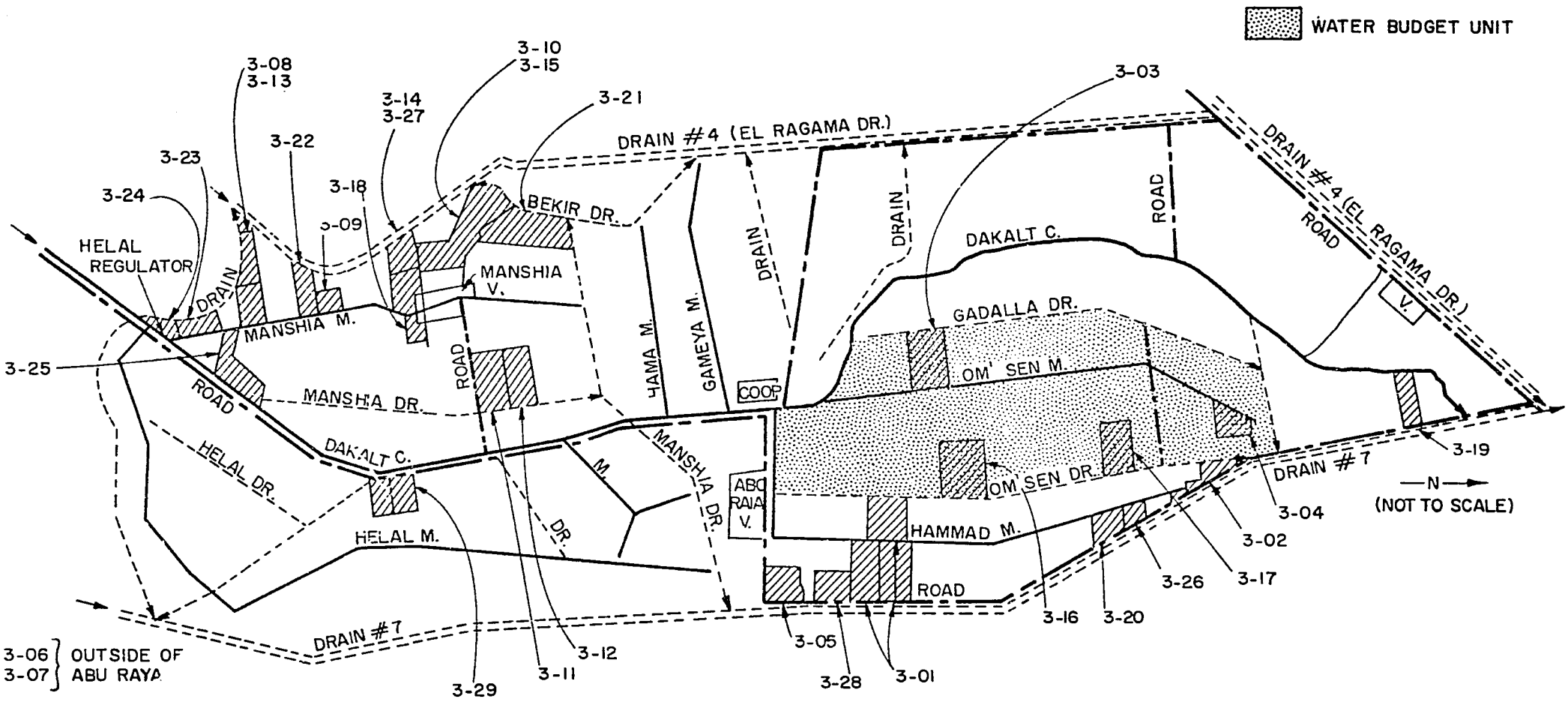


Figure 1. Map of Egypt showing the location of Abu Raya and Kafr El Sheikh Governorate.



PI PHASE SITES (SUMMER '78 - SUMMER '79)		FIELD TRIALS (WINTER '79-'80)		FIELD TRIALS (SUMMER '80)		PILOT PROGRAM SITES (WINTER '80-'81)		(SUMMER '81)		(WINTER '81-'82)		(SUMMER '82)	
3-01	(FIELD TRIALS)	3-08	3-01	3-02	3-16	3-02	3-10	3-20	3-10	3-20	3-10	3-01	3-29
3-02	3-05	3-09	3-02	3-13	3-17	3-19	3-21	3-01	3-22	3-26	3-27	3-05	
3-03	3-06	3-10		3-14	3-18		3-22		3-23			3-28	
3-04	3-07	3-11		3-15	3-10				3-24				
		3-12			3-11				3-25				

Figure 2. Map of Abu Raya Showing Irrigation and Drainage System and Farms on which EWUP has worked.

BACKGROUND INFORMATION

The term "land leveling" for irrigation is synonymous with land grading, land forming and land shaping. Each implies that the topography of a field is significantly changed. The purpose for land leveling is to allow improved control of water movement onto or from the land surface (Schwab, et al., 1966). Adding the term "precision" implies that the process is done in an exact or well-defined manner and that the objective is exact and well-defined. Precision land leveling (PLL) is then a well-defined and exact process for changing field surface topography to achieve an exact end result: a field with a planned grade to allow more efficient water application. Land smoothing is generally the term applied to the final step in PLL, which removes the minor irregularities and increases the precision.

Precision land leveling is a necessary condition for improving farm water management when surface irrigation is the method of water application. This is true when PLL is done to achieve some uniform grade in the direction of advancing irrigation water or when it is done to achieve a uniform zero grade or dead level. PLL is necessary for the removal of surface irregularities in fields which cause poor distribution of applied water, lead to salinity and waterlogging problems and result in poor water application efficiency, among other things. A review of the expected benefits of PLL illustrates why it should be considered for improving farm water management:

1. Improved irrigation application efficiencies
    a. irrigation water savings
    b. irrigation time savings
    c. irrigation labor savings.
2. Reduced salinity problems
    a. high spots receiving too little water are eliminated
    b. uniform water application improves leaching effectiveness.
3. Reduced waterlogging problems
    a. low spots receiving too much water are eliminated
    b. improved ability for applying precise amount of water reduces overirrigation; aids water table management; eliminates need for surface drains to remove excess water applied.
4. Uniform water applications for improved germination.
5. Less fertilizer losses due to overirrigation and deep percolation.

6. Higher yield should result where items 1 to 5 occur.
7. Land in production increased
   a. non-productive bunds and boundaries removed because larger fields can be irrigated as a unit (assuming other design factors are appropriate).
   b. area occupied by distribution ditches and surface drains is decreased
   c. farm mechanization is facilitated, in turn, by (a) and (b).
8. Farm water delivery losses reduced due to fewer distribution ditches
   a. improves farm irrigation efficiency
   b. reduces waterlogging problems next to farm distribution ditches.

PLL is a necessary condition for achieving the above benefits, however, it alone is not sufficient. Controlling water application in surface irrigation requires establishing the appropriate boundaries, which, in turn, is dependent upon development of an appropriate design. Surface irrigation design is dependent upon numerous physical factors such as soils, water supply, crop, climate, etc., as well as many management factors such as irrigation frequency. It thus becomes obvious that PLL, surface irrigation design and irrigation water management must be treated as a unit with each component receiving the proper development and attention. The neglect of any of these three components leads to less than optimal results. Farm irrigation system design and management considerations have been treated in EWUP (1983a). This report will focus on precision land leveling.

It must be recognized that PLL cannot be done without giving attention to limiting factors such as soil types and profiles, soil fertility, general topography, crops to be grown, irrigation method and climate. Each of these may constrain the amount of leveling that can be done, the amount of soil that may be cut, the costs that may be justified, etc. Available machinery and technical assistance (includ- ing instruments and trained personnel) may be severely limited. By way of example, each of these factors will be addressed for the Abu Raya area, so the reader will have a better understanding of how different constraints limit the ability to perform PLL in any given area. Further background information can be found in Chap. 8 of Jensen (1980), Chap. 14 of Schwab, et al. (1966), and USDA (1961).

PRECISION LAND LEVELING EXPERIENCE IN ABU RAYA

The Situation

The conventional irrigation methods used by Egyptian farmers in the Abu Raya area have been well-described in Egyptian and American Field Team(1980a), Gates, et al. (1981) and EWUP (1982a). Since rice is cultivated as a major summer crop, farmers perceive the need to keep the fields as level as possible to assist the irrigation and sub- mergence of rice. The method used is basin irrigation. Considerable effort is expended to level the land while preparing the land for rice. However, because of the methods used for doing this, farmers cannot adequately level their fields. This is evidenced in the fact that for other crops in the rotation smaller basins are used to compensate for the unlevelness and to try to achieve better water control. While this may help the levelness problem, land is taken out of production due to the large number of bunds or dikes and distribution ditches used. Also, the farmer must expend more time and effort to irrigate the numerous small plots. The problem of unlevel fields was determined by EWUP (Egyptian and American Field Team, 1980a; Egyptian and American Team, 1980b) and the suggested solution was precision land leveling to construct dead level (zero grade) basin irrigation systems. Dead levelness is required for good water management for paddy rice production.

The Need for PLL

Substantial data collected over the many seasons in which PLL was performed on numerous farms strongly supports the fact that PLL is needed in the area if on-farm water management is to be improved. The results of several selected grid surveys made on fields to be leveled for the first time are summarized in Table 1. The data of Table 1 are summarized from analyses of individual field grid surveys such as that given in Figure 3, which presents the usual information collected and the analyses made when a field is surveyed for leveling to dead level. These data inidicate a definite need for PLL in Abu Raya. For efficient level basin irrigation a field levelness standard or acceptable tolerance of $\pm$ 0.015 m (0.03 m range) from mean field elevation has been established (USDA, 1974). For furrows within level basins, the tolerance may be up to twice as much provided there are no reverse gradients in the direction of irrigation. The results in Table 1 indicate that the measured range in field elevation variation averages around 0.13 m (more than four times the acceptable

tolerance). Examining the individual cases reveals all the fields have a range at least twice the permitted tolerance, while nearly 90% have a range at least three times the permissible tolerance. It should be noted that several of the cases were surveys after a rice crop (assumed to be the best possible condition of the fields due to the farmers' efforts to level for rice). In these five cases, the range was still at least three times the accepted tolerance. It appears quite obvious that the conventional field conditions in Abu Raya result in very non-uniform water applications and significant inefficient water use, as farmers traditionally will apply water until the high spots are adequately irrigated.

The data in Table 1 indicate that, on the average, 6.5 cm of cut and fill are necessary to bring the field to dead level. The range of cut and fill indicated is from $\pm$ 3 cm to $\pm$ 12 cm. Soils in the Abu Raya area are deep, uniform, alluvial clay soils where the clay fraction averages 60% or more and sands less than 12%. The most common soil types are the Typic Torrerts of the Vertisol order (Abdel Wahed, et al. 1982). Soil survey results reported in Egyptian and American Field Team (1980a) for surface and subsurface distribution of salinity and sodicity indicate that the 0-25 cm plow layer is non-saline (EC < 4 mmhos/cm) and has low SAR (< 10) in over 80% of the Abu Raya area. Maximum cuts are expected to be in the 15 cm to 20 cm range and therefore in terms of soil type, texture, salinity and sodicity minimal adverse effects due to cuts are forecast.

A broad soil fertility survey was also conducted in Abu Raya (Zanati, et al., 1982). Results generally show that surface (0-20 cm) and subsurface (20-60 cm) soils are most often deficient in nitrogen, phosphorus and zinc. Nitrate-nitrogen availability was found to decrease with depth, as was zinc availability. Both nitrogen and zinc availability were found to be generally low to marginal for the entire profile. Phosphorus was found to be low also but increases with depth. It is concluded that maximum expected cuts in the 15-20 cm range will not adversely affect soil fertility in Abu Raya. Organic matter (OM) is generally considered low in Egyptian soils, however, due to typical practices of applying manure, the surface (0-20 cm) may have a high OM content. It is recommended that the typical practice of applying manure be delayed until just before the final smoothing.

Timing

The general cropping pattern in Abu Raya is a two-year rotation. Rice and cotton are typically alternated each summer on a given field, although maize may be substituted. Beginning with a winter crop of wheat, a typical two-year rotation is as follows: wheat - rice (or maize) - birsim - cotton - wheat. Flax

Table 1. Summary of Single Field Elevation Variation Data for Selected Fields in Abu Raya District, Kafr El Shiekh. (Adapted from EWUP, 1982a).

Farm and Strip ID	Mean Strip Elevation (m)[a]	Elevation (m)[a] Max.	Min.	Range (m)	Standard Deviation (m)	Time of Year[b]
3-01 (1)	1.36	1.40	1.32	0.08	0.03	Nov '79 (after rice)
3-01 (2)	1.33	1.39	1.30	0.09	0.02	Nov '79 (after rice)
3-02 (2)	1.55	1.61	1.49	0.11	0.03	Oct '79 (after cotton)
3-02 (3)	1.57	1.62	1.52	0.10	0.02	Oct '79 (after cotton)
3-02 (4)	1.56	1.59	1.53	0.06	0.02	Oct '79 (after cotton)
3-02 (5)	1.51	1.57	1.48	0.09	0.02	Oct '79 (after cotton)
3-02 (6)	1.49	1.56	1.45	0.11	0.03	Oct '79 (after cotton)
3-08	1.31	1.35	1.25	0.10	0.02	Nov '79 (after rice)
3-09	1.03	1.08	0.98	0.10	0.02	Nov '79 (after rice)
3-10	1.58	1.64	1.55	0.09	0.02	Nov '79 (after rice)
3-12	1.50	1.58	1.47	0.11	0.03	Nov '79 (after rice)
3-02 (A)	1.47	1.52	1.32	0.20	0.04	Nov '80 (after cotton)
3-02 (B)	1.48	1.56	1.41	0.15	0.03	Nov '80 (after cotton)
3-21 (5)	1.66	1.83	1.59	0.24	0.04	Nov '80 (after cotton)
3-23 (A)	1.43	1.49	1.37	0.12	0.03	Mar '81 (after birsim)
3-25 (5)	1.60	1.64	1.57	0.07	0.02	Jun '81 (after wheat)
3-25 (4)	1.63	1.68	1.59	0.09	0.03	Jun '81 (after wheat)
3-01 (B)	1.64	1.72	1.55	0.17	0.03	Jun '81 (after wheat)
3-27 (A)	1.00	1.11	0.92	0.19	0.05	Nov '81 (after cotton)
3-27 (B)	1.00	1.07	0.91	0.16	0.03	Nov '81 (after cotton)
3-26 (B)	1.00	1.09	0.95	0.14	0.03	Nov '81 (after cotton)
3-26 (A)	1.00	1.07	0.91	0.16	0.03	Nov '81 (after cotton)
3-01 (D)	1.00	1.07	0.88	0.19	0.04	Mar '82 (after birsim)
3-28 (A)	1.00	1.07	0.93	0.14	0.04	Mar '82 (after birsim)
3-29 (A)	1.00	1.07	0.94	0.13	0.03	Mar '82 (after birsim)
			Mean of range 0.13			

a/ Elevations given are relative to local benchmarks.

b/ Relative to 2-year crop rotation and time when rice is cultivated (Refer to Figure 1).

Source: Compiled from unpublished data collected by S. El Din, A.F. Metawie, A. El Kayal, K.E. El Din, A. Dardir, M. Awad, S. Zaki, S. Fahmy.

LAND LEVELING DATA ANALYSIS

Site 3-09(1) 79-80(W)
Abdel Halim El Zayat
13 Nov 79
Survey before scraping

Actual Field Area= 0.42 Fed
Field dimension(E-W)= 18.00 m Field dimension(N-S)= 98.00 m
Grid interval (E-W) dir.= 6.00 m
Grid interval (N-S) dir.= 10.00 m

Grid point values are elevations ↑N

0.80	0.80	0.80
1.03 ----	1.03 ----	1.04 C0.01
0.98 F0.05	1.03 ----	1.04 C0.01
1.02 F0.01	1.02 F0.01	1.05 C0.02
1.03 ----	1.00 F0.03	1.05 C0.02
1.03 ----	1.04 C0.01	1.04 C0.01
1.03 ----	1.03 ----	1.04 C0.01
1.04 C0.01	1.03 ----	1.04 C0.01
1.02 F0.01	1.04 C0.01	1.04 C0.01
1.07 C0.04	1.05 C0.02	1.08 C0.05
1.08 F0.03	1.00 F0.03	1.06 C0.03

Figure 3. Example of information collected and analyses performed when a field is surveyed for leveling to dead level. (Computer algorithm given in Ley, 1983.)

A value of 0.0 means pt. is outside of field bdy.

When no. appears in upper left corner of grid sq. it represents the size of that grid sq. as percentage of the std. grid size

Grid pt. cut/fill values are rounded to nearest (cm).

Adjusted average elevations = 1.033 m Design value= 1.030 m
Standard deviation of elevations = 2.06 cm
Total cut vol.= 16.08 mt3 Total fill vol.= 10.20 mt3
Cut Volume= 38.29 mt3/Feddan
Extra fill vol. required(drains)= 0.00 mt3
This extra fill vol. was included in the calculations
Cut/fill ratio= 1.58

and sugar beets often substitute as winter crops. In general, the periods between crop seasons when land preparation can be accomplished is mid-October to mid-December for winter crops (wheat, flax, sugar beets, birsim), late February to late March for cotton and mid-May to late June for maize and rice. Climate (rainy weather) is often a limiting factor in November - December and in March.

More specifically, the K.S. Team has found that most of its' PLL work is concentrated as follows:

1. from 15 November to 10 December for winter crops grown after cotton. Maize generally goes directly into birsim. If timing is correct, PLL after maize can be done in early October. It is not recommended to perform PLL after rice. The soil is generally still very moist and both soil compaction and machinery traction problems can result.
2. from 10-15 March to 1 April for cotton. If the weather is cooperative, farmers prefer to use the Damse method for planting cotton (i.e., pre-irrigate). This means PLL must be finished usually by 15-20 March. If the weather is rainy, then farmers will use the dry method of planting and PLL usually was performed from 20 March to 5 April. It should be noted that PLL provides many of the benefits for which farmers perform the Damse method (good seed bed preparation and uniform wetting of the furrows and plant rows). Thus the Damse pre-irrigation can be eliminated with PLL, allowing a significant water savings.
3. from 20 - 31 May for maize. PLL for maize can begin immediately after the winter crop harvest.
4. from 20 May to 20 June for rice. Begins after winter crop harvest and generally follows land preparation for maize.

It is well-known that soil tillage is best done at some optimum soil moisture content (Jensen, 1980). It is not always possible to do this in Abu Raya. Several examples illustrate this. For PLL after cotton, the soil has been drying out since the last irrigation usually about mid-August (approximately 3 months). Plowing of the dry soil brings up large, hard clods, and PLL operations were extremely difficult to perform until the large surface aggregates had been broken down sufficiently. Rainfall in early November moistens and softens the clods and helps the process considerably. Both disking and soil scraping operations were used to break down the large clods. The best soil moisture conditions for PLL occur during the period of preparing the land for cotton. Generally preceded by birsim the last irrigation was applied only 2 weeks to 2 months prior. Also, the climate

is cooler so soil evaporation is less. In doing PLL for the other summer crops similar conditions as for the "after cotton" case have been found, but to a lesser degree. In this case, the previous crop's last irrigation occurred 2 to 2-1/2 months prior. In all cases, the soil is of above average difficulty in ease of tillage. Chisel plowing to 20-cm depth in a minimum of two perpendicular directions was found to be necessary in order to begin earthmoving. Sometimes a third plowing was necessary and in all cases, cut areas required plowing before final planing.

Procedural and Logistical Factors

The reader is referred to EWUP Manual No. 8, "Thirty Steps to Precision Land Leveling in Egypt" (EWUP, 1982b) for a comprehensive description of this process from setting up and doing the grid survey to preparing the operator's map to calculating estimated earthwork volumes to final checking. Other recommended references are USDA (1961) and Chap. 8 of Jensen (1980). What follows is a description of the general procedures used by the Kafr El Sheikh Team in performing PLL in Abu Raya.

1. Sites were selected generally upon meeting with the farmer, describing what EWUP would do and obtaining agreement from the farmer that he would provide chisel plowing in at least two directions before work would start. (During the field trials, EWUP did all the plowing. During pilot program work, farmers were required to do the plowing.)
2. A pre-leveling grid survey was made of the field. (Usually before any plowing, or after plowing and then smoothing on the grid rows and columns). This survey included field drain and ditch surveys for estimating required fill volume. Generally, the grid was 10 m x 10 m. The grid size was not always square and was often adjusted according to field size, so that an even number of equal size grid squares were determined in each direction. Most often only grid stakes along exterior field edges were placed. See EWUP (1982b) for recommended method. An engineer's level, tripod, two 2-m field rods, a 20-m tape, clipboard, paper and pencils were the equipment used. The survey was usually performed with an engineer and two technicians. Survey time is dependent upon field size, but is estimated at 45 min/Feddan including setup.
3. These initial surveys were used to construct an operator's map showing the cut and fill values at each grid point. Fill volumes required for filling field drains and ditches were added in (where necessary) and

appropriate adjustments made to the average level in an attempt to obtain cut/fill ratios greater than 1.3. Cut/fill ratios greater than 1.3 did not always result due to rounding errors, etc.

4. The operator removed field drains by chisel plowing the banks and using a grader to crowd surrounding soil into the ditch until it could be driven across. Sometimes it was also necessary to chisel plow the entire field a third time to a greater depth using the EWUP tractor and implement.
5. Earthmoving was accomplished with a roll-over bucket soil scraper. In Abu Raya, the tractor driver gained enough experience to perform earthmoving using the scraper and a map of cuts and fills only. This is not the recommended procedure as stakes at the grid points showing cut and fill should be set to maintain grade control through the entire process. It was most likely successful in Abu Raya, however, because the cut and fill amounts were generally small (<15 cm). The soil scraper was used as a means of breaking down the large, dry, surface aggregates very effectively. A disk harrow had been used for this operation but was very time-consuming. During the final process, the soil scraper was used as a float to smooth the surface so a check grid survey could be made.
6. A check grid survey was generally performed. If most of the field was found to be within less than ± 4 to 5 cm of the mean field elevation, then final smoothing could be done. If not, more scraping was done. Chisel plowing in cut areas was usually necessary.
7. The field plane was used for final smoothing in cases where it could be brought to the field. In other cases, the soil scraper was used as a float for final smoothing. In all cases, the final smoothing was not considered adequate until a tolerance of ± 2 cm over 90% of the entire field was reached.

   Generally, corners were outside this tolerance as the field plane could not be maneuvered effectively there. Final checking grid surveys were performed before work was complete.

Manpower requirements for PLL in Abu Raya consisted of, at least, 1) an engineer to perform the grid surveys and calculate the cuts, fills, etc., 2) two technicians to assist in the grid surveys, and 3) a tractor driver and 2 assistants for changing implements. K.S. Team technicians have received training in tractor driving and leveling operations. A farm machinery engineer directed equipment

usage, maintenance and scheduling. Farm machinery used include the Massey-Ferguson MF265 (65 hp) tractor, a chisel plow, disk harrow, soil scraper, field plane, and grader. For irrigation system construction, the equipment used was a ditcher, a border-ridger for making bunds, and a 2-bottom lister for making furrows. Photos and descriptive captions of the various PLL operations at Abu Raya are included in Appendix A.

During the course of implementing land leveling work in Abu Raya problems were often encountered in transporting the required machinery to the farms involved, and in some cases, gaining access to the fields. Accessibility of farm lands in Abu Raya is detailed in EWUP (1983b). A physical survey of the area was made to identify roads which would allow passage of the machinery and obstructions to passage. In most instances, the tractor could be brought to the field with minimal problems. Short implements such as the chisel plow or even the soil scraper could also be brought. It was often not possible to bring the field plane to an area because of narrow roads, trees or buildings obstructing the normal road width, as well as cuts in canal banks, along which most roads are located.

A computer (HP-9825) program for performing PLL data analyses, and user instructions, which follows the procedures in EWUP Manual #8 (EWUP, 1982b), has been formulated. This program can serve several useful purposes such as checking field calculations, as an educational tool for PLL design and technical evaluation of data, as a means for providing hard copy output of the PLL design for a field and as a means for a review-approval process to be used by supervising engineers and field staff. Description of the program and user instructions have been prepared as an EWUP Manual (Ley, 1983).

PLL as Component of the Kafr El Sheikh Demonstration Programs

PLL was tested and demonstrated to farmers as a part of a package of practices during two seasons of field trials (1979 - 80 Winter and 1980 Summer). Results in terms of improved irrigation water management, crop production and farmer response were very promising. These will be discussed in a later section. The success of the package and farmer interest ultimately led to the development of the Kafr El Sheikh On-Farm Water Management Demonstration Programs on Hammad and Manshia Mesqas of which PLL is a very important component. Program implementation on farms in the Hammad and Manshia areas began with 1980 - 81 Winter season and has been an on-going process since. Details of the program have been reported in various EWUP documents including: Egyptian and

American Team, Vol. I. (1980b); EWUP (1982a). Basically the program is intended to improve the farm irrigation system through improved farm distribution ditches; precision land leveling; irrigation system design; irrigation water management advisory assistance to farmers in terms of when, how much and how to irrigate; field drain removal and/or renovation. Crop production and management recommendations are also included.

The program has been very successful on each of the new farms brought into the program each season. Farms which have continued to receive attention after their first season with the program, continue to also show improved results. These results will be discussed in a later section.

PLL has been very successful in Abu Raya. This is because it is an integral component of a package of improvements that also addresses irrigation system design and farm water management. These three components have been consistently dealt with as a unit, therefore the success of the program. It should be mentioned, however, that the general characteristics of the farm system of Abu Raya have also contributed to the success. These include:

1. relatively larger farms and/or fields (as compared to the rest of Egypt),
2. harvesting - planting gaps between seasons which are relatively fixed and orderly allowing for effective planning and implementation,
3. understanding by farmers of need for leveling (i.e., due to their attempts to level for rice),
4. strong farmer interest in mechanization and assistance in land preparation tasks.

It is expected that the program would achieve similar good results in areas of conditions similar to those in Abu Raya. Adjustments in the program can be made to allow for certain flexibility. For instance, the latest technology in precision land leveling: laser land leveling was tested on an Abu Raya Farm (see photos, App. 1). This method has an inherent advantage in that only the soil scraper is used for precision leveling, which allows for much improved machinery maneuverability in getting to the field, operating in the field (i.e., corners, narrow fields, etc.) and is very adaptable to smaller farms. The major disadvantage of this method is the laser systems are presently very expensive and would be very far from being economically feasible without outside support. Designing the farm irrigation systems based on the design considerations of an area (i.e., available flow rate, soil types, crops, climate, etc.) further gives the package flexibility for successful application.

SUMMARY AND ANALYSIS OF PLL DATA FOR ABU RAYA

The purpose of this section of the report is to provide a summary of the technical treatment of the PLL data collected in Abu Raya. The manpower requirements and inputs have been described in the previous sections. Generally involved in manpower input is performing the grid and field survey, designing the PLL process for the field, performing the PLL operations (farm machinery operation), performing check surveys, and design and construction of the planned farm irrigation system (border strips: spacing and layout; long furrows; ditches). A summary of the operations involved have also been described in the previous section. The total farm machinery input involves plowing and use of a grader for field drain removal; disking (not always necessary); soil scraping for earthmoving and smoothing; land planing for final smoothing; system construction using ditcher, furrow opener or border-ridger (a V-shaped implement used for crowding soil into a bund). Typically, however, precision land leveling requires the soil scraper, field plane and chisel plow (as necessary). Analysis in the following subsections is broken down to compare the total farm machinery basis (all operations and implements) vs. the scraper and field plane only (traditional PLL implements) basis. It is imperative to consider the total farm machinery input, as the work accomplished was not just for PLL but for the entire farm irrigation system development process, which includes PLL as a component, as well as modification of system layout and construction of new designs (level border strips and long level furrows and new distribution ditches).

Table 1 in the previous section illustrated the need for PLL in Abu Raya and also gives the reader an idea of the amount needed (in terms of cuts and fills). Data available for analysis in this section of the report are from the 1979 - 80 Winter season field trials and three seasons of pilot program work: 1980 - 81 Winter, 1981 Summer and 1981 - 82 Winter. Tables of summary data including farm machinery hours of operation, estimated farm machinery costs, estimated earthwork volumes and estimated costs for each of the several sites of each of these seasons are presented in Appendix B. Tables B1 and B2 are for the 1979 - 80 Winter season. Tables B3 - B5 are for the 1980 - 81 Winter season. Tables B6 - B9 are for the 1981 Summer season cotton crop. Tables B10 - B13 are for the 1981 Summer season rice and maize crops. Table B14 - B16 are for the 1981 - 82 Winter season.

Estimated farm machinery costs are based on farm machinery cost tables developed by EWUP during 1979. (EWUP Staff Paper #8, 1979). The hourly cost of operation of tractor and implement was estimated based on capital costs and operation and maintenance costs for a given total annual use in hours. Records of the hourly use of the different implements and tractor were kept during all PLL operations for the above seasons. It was possible from this to develop estimates of the farm machinery costs on a unit area basis for PLL on Abu Raya farms. These estimates comprise several of the Tables in Appendix B.

The estimated costs in Appendix B are limited to the farm machinery capital, operation and maintenance costs. The costs for an operator are included. Costs not included in the following (and also not estimated) are: 1) costs of technical and professional personnel, 2) costs of transporting machinery to and from the field, 3) costs due to machinery field efficiency being less than 100% (i.e., time lost in turning, changing implements, etc.). Thus, real costs to the farmer will be higher than those which follow.

Grid surveys were typically performed before any farm machinery work so that the initial PLL design could be formulated, and then after scraping and land planing operations as checks. The grid survey for the initial design was used in all cases to estimate earthwork (cut and fill) volumes using the summation method (EWUP, 1982b). These volumes represent the amounts necessary to bring the field surface to dead level. For practical purposes this was not done. Most PLL work in Abu Raya was considered complete when 90% of the field was within $\pm$ 2 cm of the mean field elevation (i.e., this was the arbitrary goal of PLL work by the K.S. Team in Abu Raya). Thus, the <u>actual</u> earthwork volumes would be the differences of those estimated from pre- and post-construction surveys. Unfortunately, the post-construction surveys were not always available or are missing. Therefore, for the purpose of comparison, all of the earthwork volume data reported in Appendix B is from pre-construction grid survey estimates. These values are then used to estimate land leveling costs on a per cubic meter of cut volume basis (for both the total farm machinery, and scraper and field plane only cases). For some sites, post-construction grid surveys are available and the differences in the estimated cut and fill volumes have been determined. These data will be discussed later.

A summary of the 4 seasons of PLL data given in Tables B1 - B16 is presented in Table 2. The mean estimated cut volume data are, as discussed, based only on the initial grid surveys. An overall mean of approximately

Table 2. Summary PLL Data for 4 Seasons at Abu Raya, Kafr El Shiekh.

Season	Mean Estimated Cut Volume (m^3 Fed)[1/] (± Std. dev.)	Mean Estimated Costs (± Std. Dev.) (LE/Fed)[2/] Total Farm Machinery Basis	Scraper and Field Plane Only	(LE/m^3) Total Farm Machinery Basis	Scraper and Field Plane Only
1979-80(W) (7 sites)	53.8 (± 22.4)	33.96 (±12.92)	17.02 (± 8.10)	0.76 (±0.21)	0.38 (± 0.15)
1980-81(W) (9 sites)	81.9 (± 41.9)	19.39 (± 8.15)	11.89 (± 6.30)	0.29 (± 0.18)	0.18 (± 0.15)
1981 (S)					
Cotton (14 Sites)	57.7 (± 23.0)	15.04 (± 4.28)	9.64 (± 3.09)	0.29 (± 0.10)	0.18 (± 0.06)
Rice (2 sites)	39.8 (± 11.0)	14.70 (± 6.99)	12.41 (± 5.44)	0.36 (± 0.07)	0.31 (± 0.05)
Maize (3 sites)	52.3 (± 19.0)	16.48 (± 5.56)	8.35 (± 8.12)	0.32 (± 0.09)	0.14 (± 0.11)
1981-82 (W)					
4 Sites (1st time)	69.3 (± 24.1)	33.32 (± 11.18)	25.28 (± 10.41)	0.50 (± 0.14)	0.38 (± 0.14)
3 Sites (2nd time)	32.5 (± 3.6)	15.75 (± 5.63)	14.23 (± 4.75)	0.48 (± 0.17)	0.44 (± 0.16)
Mean[3/]	59.1 (± 14.7)	22.15 (± 9.06)	14.10 (± 6.23)	0.42 (± 0.18)	0.26 (± 0.11)

1/ Estimated Cut Volume based on initial grid survey data. Actual cut volume will be less.
2/ Farm machinery costs based on 1979-80 EWUP farm machinery cost tables.
3/ Excluding 81-82W 2nd time sites.

59 m^3/Feddan was determined, with a range of from 40 m^3/Feddan to 82 m^3/Feddan. For the '81 - '82 Winter season, three sites were "touch-up" leveled and the estimated cut volume was much less: 32 m^3/Feddan. Estimated cost data for these estimated cut volumes are also summarized in Table 2. Mean total farm machinery costs (based on 1979 - 80 cost tables) were estimated at about LE 22/Feddan with a range from LE 14.70 to LE 33.96/Feddan. On a cut volume basis this translated to approximately LE 0.42/ m^3 of cut volume with a range from LE 0.29 to LE 0.76 per m^3. For the case of charging PLL to scraper and field plane operations only, the mean costs of LE 14.10/Feddan with a range from LE 8.35 to LE 25.28 per Feddan, and LE 0.26/ m^3 of cut volume with a range from LE 0.14 to LE 0.38 per m^3 were determined. The latter case exhibits the lower estimated costs.

Actual cut volumes will be less than those indicated in Table 2 and corresponding costs will thus be higher. Presenting the information in Appendix B and Table 2 on the basis of cut volume as estimated from the initial grid survey only serves several purposes:

1. Data from all the sites through the 4 seasons included can be compared.
2. Trends over the seasons can be determined when a standard basis is used.
3. Inclusion of larger number of sites (all having same basis for comparison) allows for determination of a "more representative" estimated mean condition.

Some comparisons from season to season show that estimated cut volumes necessary are relatively uniform (mean of 59 m^3/Feddan with coefficient of variation around 25%). Land leveling costs are seen to decrease from the 79 - 80W season to succeeding seasons. The 79-80 W season was the first major effort to do PLL in Abu Raya and much time was consumed in training. This is reflected in the higher estimated costs. For the 80 - 81 W season (the third season of PLL) and the 81 S season (the 4th PLL season) costs seem to have stabilized (LE 15 to 20 per Feddan and LE 0.30 to 0.35 per m^3 for the total farm machinery basis; and LE 8 to LE 13 per Feddan and LE 0.20 to LE 0.30 per m^3 for the scraper/field plane only basis). Estimated costs are seen to rise again during the 81 - 82 W season. This is due to the fact that major effort to train at least one professional staff member and two technicians in farm machinery operations for PLL was undertaken. An increase in the average total time per Feddan for the

component operations is observed due to this (see Appendix B, Table B14). A general trend is also seen which shows that estimated costs per m^3 are less for the greater estimated cut volumes and vice-versa.

The data available in the literature show that the amount of necessary earthmoving estimated in Abu Raya (59 m^3/Feddan, the actual is less; equivalent to 74 yd^3/acre[1/]) is very small in comparison. Typical earthmoving volume in the U.S. has been on the order of 300 - 600 yd^3/acre. Associated costs were from \$0.20 to \$0.60 per yd^3. Johnson, et al. (1978) reports on PLL in Pakistan where an average of 250 yd^3/acre was moved at an average cost of about \$0.25 per yd^3. The amount of earthmoving done in Abu Raya (74 yd^3/acre) is small, while the associated estimated costs are higher (about \$0.56/ m^3 [2/] for the total farm machinery basis and about \$0.35/ m^3 for the scraper/field plane only basis). These results indicate PLL is being done in Abu Raya for relatively small amounts of earthwork. For this report, the summation method, the least accurate, was used for estimating earthwork volumes. More accurate methods are significantly more complicated and time-consuming, unless a computer algorithm is used. For such small earthwork volumes, the possible error as a percent of the total may be large when the summation method is used. The variation from field to field is also relatively large.

In Table 3, pre- and post-construction survey estimates of cut volume are compared and the "measured cut volume" is determined. For the pre-construction surveys, note that the C/F ratios given are quite variable and not always greater than 1.3. The design elevation for any given field was usually adjusted in increments of 0.5 cm when accounting for extra fill volume and attempting to obtain C/F ratios greater than 1.3. However, cut and fill depths at each grid point were rounded to the nearest centimeter. Consequently, cut and fill volume estimates are affected by this rounding error to the point where the wide variation in C/F ratios were obtained. Post-construction surveys are check surveys to determine the deviation of the grid points from the mean and if they are within the specified tolerance. In this case, cut and fill volume estimates were equal, i.e. no attempt was made to obtain a C/F ratio greater than 1.3.

1/ 1 m^3/Feddan = 1.26 yd^3/acre.

2/ 1980 exchange rate of LE 0.75 = \$1.00 assumed.

Table 3. Comparison of pre- and post- construction grid survey estimates of cut and fill volumes for sites with available data, Abu Raya, Kafr El-Sheikh.

Site (Season)	Area (F)	Pre-construction Cut (m^3)	Pre-construction Cut (m^3/Fed) (1)	Pre-construction Fill (m^3)	Pre-construction C/F	Post-Construction Cut (m^3)	Post-Construction Cut (m^3/Fed) (2)	Post-Construction Fill (m^3)	Post-Construction C/F	Measured Cut Volume (2)-(1) (m^3/Fed)
3-09(1) (79-80W)	0.42	16.1	38.3	10.2	1.58	12.1	28.9	12.1	1.00	9.4
3-10-A (80-81W)	0.94	72.8	77.5	71.3	1.02	22.5	23.9	22.5	1.00	53.6
3-10-B (80-81W)	1.84	146.1	79.4	134.3	1.09	56.6	30.8	56.6	1.00	48.6
3-21 (80-81W)	3.03	253.0	83.5	207.0	1.22	81.0	26.7	81.0	1.00	56.8
3-10-A (81S Cotton)	0.95	66.0	69.5	40.0	1.65	16.9	17.8	16.9	1.00	51.7
3-10-B (81S Cotton)	1.15	64.0	55.7	45.0	1.42	32.5	28.3	32.5	1.00	27.4
3-22-A (81S)	2.14	239.0	111.7	195.0	1.23	48.0	22.4	48.0	1.00	89.3
3-22-B (81S)	1.19	108.0	90.8	77.0	1.40	47.0	39.5	47.0	1.00	51.3
3-24-A (81S)	1.59	35.6	22.4	30.7	1.16	21.3	13.4	21.3	1.00	9.0
3-23-A (81S)	0.74	39.0	52.7	35.5	1.10	22.0	29.7	22.0	1.00	23.0
3-20 (81s)	4.48	178.7	39.9	153.1	1.17	104.0	23.2	104.00	1.00	16.7
3-25 (81S)	4.3	137.5	32.0	106.0	1.30	81.5	19.0	81.5	1.00	13.0
3-01 (81S)	2.1	100.0	47.6	93.6	1.07	63.0	30.0	62.0	1.00	17.6
3-10-A (81S Maize)	0.72	31.0	43.1	23.0	1.35	22.7	31.5	22.7	1.00	11.6
3-10-B (81S Maize)	0.53	21.0	39.6	16.0	1.30	13.0	24.5	13.0	1.00	15.1
3-26-A (81-82W)	2.05	119.0	58.1	98.0	1.21	43.8	21.4	43.8	1.00	36.7
3-26-B (81-82W)	2.64	190.0	72.0	100.0	1.90	100.0	37.9	100.0	1.00	34.1
3-27-A (81-82W)	1.92	195.0	101.6	151.0	1.29	42.0	21.9	42.0	1.00	79.7
Mean (± Std. dev.)			62.0(±25.2)				26.2(± 6.7)			35.8(±24.4)

On the average, for the 18 sites where data were available, the measured or actual cut volume is about 36 m^3/Feddan. There is a large degree of variation, however. The mean estimated cut volume (59 m^3/Feddan) using the pre-construction survey is 164% of the mean measured value (36m^3/Feddan). In Table 4, the cost data for the sites in Table 3 are used to determine an average cost of LE 0.71/ m^3 for the total farm machinery basis and LE 0.43/ m^3 for the scraper/field plane basis. Compared to Table 2 values, these costs are 69% and 65% larger, respectively. The above results roughly indicate that, for Abu Raya, the actual cut volume may be overestimated by ⅔ when only initial grid survey data are used, and the estimated costs (on a per m^3 basis) are only about ⅔ of the actual costs. It is emphasized again, that the earthwork volumes involved (mean measured cut volume of only 36 m^3/Feddan (45 yd^3/acre) are relatively very small. Inaccuracies with determination of earthwork volumes may represent a fairly large percentage of this mean value. A certain amount of caution is necessary when reviewing the above results. Because of the PLL process used by the K.S. Team, in which grade control at grid points was not kept established for the duration of the process from pre- to post-construction surveys, a certain amount of error in the reported actual earthwork volume may exist. For instance, it cannot be said with certainty that the cut or fill at any given grid point was actually made according to the specifications of the initial grid survey. It is likely the post-construction grid points were in slightly different location relative to the initial survey points. Thus, a direct comparison of the cuts or fills necessary at a grid point to reach the desired grade, from pre- to mid- to post-construction surveys is not possible. This is a major drawback of the methods used in Kafr el Sheikh for PLL. The methods outlined in EWUP (1982b) should be closely followed. Grid stakes should be established and respected.

The goal of PLL work in Abu Raya was to attain within ± 2 cm from the mean elevation at 90% of the grid points for any field. Jobs were not considered complete until post-construction surveys verified this goal. For this reason, the actual earthwork volumes reported herein are still considered accurate and representative.

In concluding this section, it is necessary to touch on the subject of maintenance of PLL (to dead level or any other grade). Some representative data in Appendix B and in Table 2 are for sites receiving PLL the second time. Essentially, this was a "touch-up" operation, as the estimated earthwork volumes are seen to be small. The concept of having to perform PLL each season to maintain dead level is incorrect. Typical farmer tillage operations and soil

Table 4. Estimated Farm Machinery Costs Based On Measured Cut Volume, Abu Raya, Kafr El Sheikh.

Site (Season)	Measured[1/] Cut Volume (m^3/Fed)	Estimated Costs (LE/Fed) Total F.M.	Estimated Costs (LE/Fed) Scraper/ Field Plane	Estimated Costs (LE/m^3) Total F.M.	Estimated Costs (LE/m^3) Scraper/ Field Plane
3-09(1) (79-80W)	9.4	18.82	8.19	2.00	0.87
3-10-A (80-81W)	53.6	11.59	4.76	0.22	0.09
3-10-B (80-81W)	48.6	12.26	9.71	0.25	0.20
3-21 (80-81W)	56.8	12.24	10.74[2]	0.22	0.19
3-10-A (81S Cotton)	51.7	19.63	14.62	0.38	0.28
3-10-B (81S Cotton)	27.4	12.79	8.92	0.47	0.33
3-22-A (81S)	89.3	15.61	10.85[2/]	0.17	0.12
3-22-B (81S)	51.3	12.27	10.00[2/]	0.24	0.19
3-24-A (81S)	9.0	8.41	4.90[2/]	0.93	0.54
3-23-A (81S)	23.0	13.54	9.37[2/]	0.59	0.41
3-20 (81S)	16.7	18.89	13.37	1.13	0.80
3-25 (81S)	13.0	9.76	8.56[2/]	0.75	0.66
3-01 (81S)	17.6	19.64	16.26	1.12	0.92
3-10-A (81S Maize)	11.6	17.91	6.44[2/]	1.54	0.56
3-10-B (81S Maize)	15.1	10 32	1.35[2/]	0.68	0.09
3-26-A (81-82W)	36.7	23.38	16.78	0.64	0.46
3-26-B (81-82W)	34.1	28.99	19.02	0.85	0.56
3-27-A (81-82W)	79.7	49.28	39.90	0.62	0.50
Mean (± Std. dev.)	35.8(±24.4)	-	-	0.71(±0.50)	0.43(±0.27)

1/ from Table 3.

2/ Scraper only, field plane could not enter field.

settlement in fill areas mandates the need for further surface smoothing. However, the actual need for further earthmoving (even compared to typical Abu Raya conditions) does not exist. Rather, the need for maintenance of dead level for efficient water application does exist, and field smoothing/floating on a seasonal basis is recommended. In the U.S., this practice is a normal seasonal land preparation (cultural) practice which farmers' use. It should be viewed as such in any area where PLL is performed. PLL is performed in the first season, but smoothing and floating become a normal seasonal practice thereafter to maintain the grade obtained by PLL.

IMPACT OF PLL ON IMPROVING ON FARM WATER MANAGEMENT IN KAFR EL SHEIKH

Hypotheses

The expected benefits of PLL have been listed in a previous section. As PLL in Abu Raya was tested, and later made an integral part of the farm water management improvement demonstration program there, it was expected that each of the benefits listed could be evaluated for the Abu Raya conditions.

Generally, because of what EWUP problem identification studies in Abu Raya had revealed (Egyptian and American Teams, 1980a; 1980b), the following parameters received the most attention in assessing the impact of PLL on improving farm water management in the area:

1. farm irrigation efficiency, the ratio of amount of water stored for use by the crop to the amount of water lifted at the saqia; water application efficiency, the ratio of amount of water stored for crop use to the amount of water applied to the field; farm conveyance efficiency; the ratio of the amount of water applied to the field to the amount of water lifted at the saqia;
2. irrigation water savings, application of proper amount at correct time;
3. irrigation time and labor requirements;
4. water table levels, drainage, soil salinity;
5. crop production levels;
6. farm and field layouts, productive land area;
7. stability of results achieved;
8. farmer reaction and response.

The first 6 items above are treated in a review of the seasonal results in the following subsection. Items 7 and 8 are treated in separate succeeding subsections.

It must be noted, that at no time during any of the seasons when PLL was performed on farms in Abu Raya, was it done so that the impacts due solely to PLL could be evaluated. Reasons for this include the fact that the approach taken to the work performed in Abu Raya was not an "experiment-station" approach. Actual operational farms were being used, so land area available for such testing was limited. Economics dictated the approach taken as funds, personnel and equipment were limited. PLL was implemented as an integral component of a package of practices, most importantly, in combination with farm irrigation design and farm water management input to farmers. It has been emphasized before that this package approach is necessary for success. The package also included crop production and management advisory assistance (i.e., seed, fertilizer, pest control and other cultural practices). Also, it was desirable to implement a broad-based approach to improving farm water management and crop production in Abu Raya. Finally, the benefits of PLL have been well demonstrated throughout the world and it was not necessary to repeat years of research to prove the same thing for Abu Raya conditions or for areas with similar conditions.

Seasonal Results

1979-80 Winter Season. Precision land leveling and dead level border irrigation design were significant elements of a package of practices tested in field trials on the wheat crop on seven Abu Raya farms during this season. Also tested in the package were a recommended new variety (Sakha 8), zinc sulphate application, fertilizer recommendations, field drain removal and water management recommendations for irrigation timing and frequency. In general, the package of practices was implemented on one or more level border strips on each farm. A field of wheat managed by the same farmer using the conventional methods was located nearby. Detailed measurements were made on both through the season to evaluate the package being tested.

This was the first season of precision land leveling to dead level by the K.S. Team. Significant training was conducted with TDY input from the U.S. A total of about 12.5 Feddans was precision leveled on the 7 farms. The level border strips constructed had lengths between 50 m and 100 m, however, strip widths were confined to 9 m to 11 m.

Measurements were taken through the season, evaluated and summarized, to formulate comparisons between the mean results for each management condition of the field trials. These results have been reported in EWUP (1981b) and further information is provided there. Generally, the mean results showed that the package of improvements gave an increased farm irrigation efficiency (62% vs. 38%), increased wheat grain yield (1.6 Ton/Feddan vs. 1.1 Ton/Feddan), reduced total water lifted for irrigation (65 cm vs. 87 cm), and reduced total irrigation time (1304 min./Feddan vs. 1907 min./Feddan). Precision land leveling and the level border design must have been a significant part of these improvements, especially the irrigation improvements, although the individual effects cannot be separated out. Assistance given to the cooperating farmers by K.S. Team members in relation to irrigation frequency, timing and amount also contributed to the improvements. Without this key input, it is expected that results would not have been as successful. The first season of tests thus showed that the design improvements bring about increased efficiency; water, labor and time savings; and improved crop yield when compared to the conventional methods. Where field drains were removed, no adverse effects were found (i.e., water table or salinity buildup). Field drain removal increased the productive area and contributed to an overall greater total farm yield.

1980 Summer Season. Field trials on the summer crops of rice, cotton and maize were conducted. The trials for each crop were designed so that four sets of conditions were tested:

1. A_o B_o was designated the "do-nothing" condition or the farmers' conventional irrigation and crop cultural practices.
2. A_o B_1 was the farmers' conventional irrigation practice with EWUP-recommended crop cultural practices.
3. A_1 B_o was EWUP recommended irrigation practices with the conventional farmer crop cultural practices.
4. A_1 B_1 was combined EWUP recommendations for irrigation and crop cultural practices.

Recommended irrigation practices were precision land leveling to dead level, level irrigation system design (dead level borders for rice, dead level long furrows for cotton and maize), advice to farmers on irrigation timing, frequency and amount and field drain removal. Six sets of trials were conducted on cotton, three on rice and two on maize. Measurements were made through the season to evaluate each condition of the trials. Results for the cotton crop have been

summarized and reported in EWUP (1981d). Results for the rice crop are included in EWUP (1982a).

For the cotton trials, the level furrow systems designed had furrow lengths ranging from 80 m to 140 m, furrow spacings of 55 cm and typical strip widths of 13 m to 18 m. This means there were about 24 to 32 long furrows in each strip (where the irrigation improvements were tried). The farmers conventional methods were on gross strip areas of the same size, but this area was always divided up into the small basins (typically 15 m to 20 m square) with furrows inside. Given the typical saqia discharge for Abu Raya, between 10 and 12 long furrows were irrigated in one set during each irrigation. This normally meant each furrow received at least 2 lps. As the season progressed, it became clear that the long furrows constructed were not being well-maintained and also had not been built large enough to begin with, i.e., there was furrow overtopping and surface flooding occuring. Large, well-defined and well-maintained furrows are necessary for successful dead level long furrow irrigation. Water control was being lost and thus the irrigation efficiency was less than desired. The mean results indicate this. The improved method and the conventional method both yielded the same farm irrigation efficiency, about 52%, and the same amount of water lifted, about 105 cm. Mean yields were much higher on the A_1 B_1 and A_1 B_0 cotton strips, 36% and 28%, respectively, due to improved crop cultural practices including the better seed bed preparation given by land leveling. Improved furrow construction and maintenance would be necessary before the long level furrows would be an improvement over the conventional methods.

For the rice trials, the level borders designed were patterned after the wheat trials: strip widths of 10 m and lengths from 70 m to 120 m. The mean results showed that the level systems gave a 14% water savings while yield levels were maintained. Further improvement could be possible if farmers practiced better dike maintenance (to reduce perimeter seepage and leakage losses) and if they followed recommendations to irrigate less frequently, once per "on" period or once each eight days, as opposed to the conventional once each four days.

For the maize trials, the long level furrows had lengths of 70 m to 85 m, furrow spacings of 70 cm and typical strip widths of 10 m. This means there were about 15 furrows per strip. The wider furrow spacing allowed construction of larger furrows and the improved results show the benefit of this. The mean results on the "improved" strips showed a 39% water savings. Accurate yield

measurements were not obtained due to a severe stem borer infestation. The available data do show that yields were about the same regardless of the practices. The irrigation experience with the long level furrows was better for the maize trials due to the wider furrow spacing and better furrows.

1980-81 Winter Season. A farm irrigation system improvement demonstration program designed after the field trials practices was implemented. This program includes improvements to the farm irrigation system through layout redesign, marwa improvement, land leveling, level irrigation system design, irrigation water management advice (frequency and amount of irrigation), and field drain removal. Farm crop production was also addressed through agronomic recommendations for improving crop cultural practices, fertilizer use, pest control, etc. Several saqia units, the areas or farms served by one saqia were to be chosen each season for improvement. The work would include all farmers and crops (if possible) on that unit during the season. Farms on Hammad and Manshia mesqas would be considered.

For the 1980-81 Winter season 5 farms were chosen. Wheat, flax, birsim, broadbeans and sugar beets were the winter crops grown on these farms. A total of about 20 Feddans was leveled and a wide range of designs considered so that more detailed evaluation of the designs could be conducted. It is pointed out here that strip configurations from long and narrow (12 m x 130 m) to square (45 m x 45 m) were tested. Long level furrows were constructed for sugar beets. Lengths were up to 50 m for the one site where beets were grown.

Considering the results for the wheat crop, where the main emphasis was placed, the same types of improvements were found this season as for the wheat field trials of the previous year. The mean farm irrigation efficiency was measured as about 52%, lower than the field trials of the previous year but still much better than the conventional method, which ranges between 30% and 40%. The water application efficiency was about 70%. The high farm conveyance losses (about 30%) caused the low irrigation efficiency. Mean total water applied was 51 cm. The mean total irrigation time of 1534 min/Feddan was 20% less than the conventional method. Mean wheat grain yield on the 5 pilot farms was measured to be 33% greater than the Abu Raya average. Soil salinity was measured several times during the season on each site. Generally, a net decrease in soil salinity levels in the 0-60 cm profile over the season resulted. Many field drains were removed and major layout changes implemented on these farms. After PLL operations, new ditches (marwas) were constructed along with the

designed irrigation strips and furrows. On one of the sites distribution marwas were reduced from 545 m total length to 285 m total length. Seven field drains were removed (457 m). Combined, this represented an increase in productive land of about 6% for the farm. A more efficient layout and farm water distribution system resulted. Further data analysis and information on the results are given in EWUP(1981c) and EWUP (1981e).

1981 Summer Season. Seven farms were chosen for the demonstration program this season. Cotton was grown on six of the farms, rice on three and maize on two. A total area of 35 Feddans was leveled.

Much better success was achieved with the long level furrows this season. Beds (Mastabas) with two crop rows for each furrow were constructed. The effective furrow spacing for both cotton and maize became 110 cm this season. The implement used for making furrows was better suited to making larger, deeper and well-defined furrows for this spacing. As a result, the irrigation results for the level furrows were much improved. Mean water application efficiency was 76% for cotton and 74% for maize. Mean total depth applied for cotton was 76 cm and 84 cm for maize. These values represent significant water savings when compared to the conventional methods. The mean pilot farm yields for cotton and maize were measured to be 16% greater and 52% greater, respectively, than the Abu Raya averages.

Measurements on the rice farms indicate a mean total application of 179 cm, much less than the conventional method average (200 cm or more). Rice farm mean yield was measured to be 27% greater than the Abu Raya average. Rice cultivation in Abu Raya is a very effective soil salinity management tool. A net average decrease of 40% has been measured during two seasons on different farms due to paddy rice. Precision land leveling to dead level increases the effectiveness of this. Field drain removal and improvement of marwas on at least one of the farms continued to make the farm layout more efficient.

Further information and results on the 1981 Summer season program work in Abu Raya are given in EWUP (1982a) and EWUP (1982c).

1981-82 Winter Season and Other Program Work. For this and future seasons, the number of new farms on which the program work was to be implemented was scaled back somewhat. The stability of the land leveling and irrigation improvements over time and farmer acceptance and continued use of the recommended practices on the previous sites was to be further evaluated.

The 1981-82 Winter season included two new farms and two previous farms. Heavy emphasis was placed on improving the farm layout and water distribution system. Two methods to reduce farm conveyance losses: plastic lining of marwas and lay-flat tubing were tested. A total of about 16 Feddans was newly leveled or "touch-up" leveled during the program. Wheat, barley and birsim fields were designed for level border irrigation with strip lengths from 50 m to 120 m and widths from 13 m to 35 m. Sugar beets and broadbeans were grown on dead level long furrow systems. The furrows were again constructed using beds. Furrow spacings were 110 cm and lengths from 50 m to 105 m.

Preliminary results for the wheat and barley show that mean irrigation efficiency was about 70%. Mean water application efficiency was 74%. Farm conveyance losses were reduced to practically zero. Mean total depth applied was about 41 cm. Mean total irrigation time was about 1400 min/Feddan. All of these figures continue to illustrate the consistent irrigation system performance improvements produced by land leveling and level irrigation system design as compared to the conventional methods. The mean wheat grain yield on pilot farms this season was 29% greater than the Abu Raya average. Crop production improvement continues to be a benefit of the pilot program package, also. (See EWUP, 1983c).

For the 1982 Summer season, a total area of about 37 Feddans was leveled or "touch-up" leveled under the program. Heavy emphasis was again placed on marwa improvement using plastic lining. A laser land leveling system was used on one of the farms. The maneuverability of this equipment and speed with which this leveling was completed are considered important advantages for this system. However, this observation is limited to the one field experience of the Team. The laser system is very expensive compared to the traditional methods of PLL and it is likely not economically feasible. Level border and level furrow designs were implemented on the farms.

Summary of Impacts

Precision land leveling and level irrigation system design have been significant components of packages of practices to improve farm irrigation systems in Abu Raya as tested and implemented by the Kafr El Sheikh Team over the past 3 years (6 crop seasons). The entire irrigation system was improved through farmer organizations developed to do mesqa cleaning and through EWUP/MOI interaction to get branch canal and drain cleaning done in the area.

The work done in Kafr El Sheikh has been to modify the farm irrigation system layout such that:

1. land leveling is more easily accomplished, as well as other forms of mechanization,
2. farm water distribution is only as extensive as necessary through elimination of excess marwas and using new marwas,
3. ineffective field drains are eliminated,
4. level border strips are laid out in an effective arrangement for basin crops,
5. effective layout of long level furrows replace the conventional furrows in small basins for row crop irrigation.

As has been consistently demonstrated in Kafr El Sheikh, when the above design improvements are combined with better water management practices (how to irrigate, when to irrigate, and how much to apply) then significant system improvements can result. Generally, these improvements include improved irrigation efficiency, water savings, labor savings, time savings, and improved crop production. Other benefits such as improved farm layouts, more efficient farm water distribution and conveyance, and water table and soil salinity management have resulted. Crop cultural and production practices recommendations also have significantly contributed to crop production improvements. The emphasis here has been that the improvements to the farm irrigation system will have a very positive impact, i.e., compared with the traditional methods farmers use in Abu Raya. It must be emphasized, however, that the improvements require farm machinery inputs for land leveling and trained personnel (such as EWUP's) for land leveling, level irrigation system design and teaching and advising farmers on improved farm water management.

Stability of Results

Current cultural practices in Abu Raya can have a devastating effect on the dead level grade established through PLL. These are: 1) scraping of topsoil after harvest for construction of bricks or for use as animal bedding, 2) addition of animal bedding material (from no. 1) to fields in small mounds without uniform spreading, 3) incomplete washing of mud from rice seedlings when transplanting occurs causing rice nursery areas to continually become lower than the remaining field areas. The impact of these practices is currently being assessed by the K.S. Team. The recommended seasonal (or yearly) practice of smoothing using a land or field plane - type device would effectively alleviate these problems and assist the maintenance of a dead level grade.

The preceding sections discussed the marked improvements in farm water management on sites which were involved in the K.S. Team's demonstration program for the first time. Several of these sites were involved in the program in succeeding seasons. The work accomplished in succeeding seasons on those farms was a limited amount of PLL (mostly smoothing), construction of the appropriate level basins or long furrows, and advice to the farmer through the season on water management and crop production practices. A limited amount of measurements are available for comparison of the results obtained on these farms during succeeding seasons with the typical results of the conventional methods. These results are presented in Table 5. The data in Table 5 allow comparison of the typical results of the conventional methods with the results obtained on farms which continued with the program, but to a less-intensive degree. Generally, it is felt that these results support the concept that a program, such as that at K.S., can produce results consistently at improved levels of performances compared to the conventional methods. It is important to note, however, that these results are for farms which did receive continued input from the K.S. Team. Farms which were not considered after only one season of input are not included and no data areavailable of the results obtained on those farms after the EWUP improvement work. The ability of farmers to continue such a program with and without continued technical assistance, the results obtained with and without continued technical assistance and the length of time required for farmers to accept and adopt the improvement practices are issues which need to be evaluated in this regard.

Farmer Response

Farmer reaction, response, interest and insight to the farm water management improvement practices, including PLL, have been evaluated for several of the seasons (both field trials and pilot programs). This has been done through implementation of a survey after each season. The survey was designed, and improved upon each season, by the EWUP Main Office and K.S. Sociologists. Results for the 1980 Summer season are reported in EWUP (1981a), results for '80-'81 Winter in EWUP (1981c) '81 Summer in EWUP (1982c) and '81-'82 Winter in EWUP (1982c).

In general, the farmer response has been very promising. Initially, it seemed the farmer reaction and interest was somewhat misplaced. The farmers viewed the PLL activities of the project mainly in the light of the farm machinery input and labor and time savings this created for the farmer. This was understandable, as the farm machinery in the area is practically non-existant or expensive to purchase and/or rent.

Table 5. Compairson of Typical Results of Conventional Methods With Results Obtained On Three Farms for the Initial and Succeeding Seasons of EWUP's Demonstration Program in Abu Raya

Season	Crop	Irrigation Eff. (%)	Depth Lifted (cm)	Total Irrig. Time (hr/fed)	Mean Yield Per Feddan Grain	Straw
TYPICAL RESULTS OF CONVENTIONAL METHODS 1/						
79-80	Wheat	38	87	31.8	1.08T	5.08T
80S	Cotton	52	102	38.5	6.8 qintar	
80S	Rice	n/a	195	n/a	3.5T	6.7T
81-82W 2/	Sugar Beet	n/a	41	18.9	15.9T	----
RESULTS ON DEMONSTRATION FARMS (Initial & Succeeding Seasons)						
Site 3-10-1						
79-80W	Wheat	67	56	24.4	1.31T	4.0T
80S	Rice	n/a	174	n/a	3.5T	8.0T
81S	Cotton	50	107	43.4	8.1 qintar (6.4 qintar) (Abu Raya Mean)	
81-82W	Wheat	65	36.8	24.9	2.5T (1.6T (Abu Raya Mean)	3.4T 3.7T)
Site 3-10-2						
80S	Cotton	78	78	26.3	6.4 qintar	
80-81W	Wheat	54	61	30.0	2.1T (1.4T (Abu Raya Mean)	6.3T 3.7T)
81S	Rice	n/a	179 3/	53.2 3/	3.0T (2.6T (Abu Raya Mean)	7.0T 4.9T)
Site 3-20-1						
81S	Cotton	80	70	23.3	7.3 qintar (6.4 qintar) (Abu Raya Mean)	
81-82W	Wheat	83	34.2	18.6	1.8T (1.6T (Abu Raya Mean)	4.1T 3.7T)
81-82W	Sugar Beet	75	50.5	30.2	26.1T	

1/ Measured during field trials

2/ Measured on economics sites

3/ Mean of all demonstration farms

n/a means not available

In later seasons, as the program became better established, as more farmers were made aware and as more of the PLL and irrigation system improvement work was demonstrated, the farmer interest grew and the response was a greater number of requests for work to be done than EWUP could accommodate. The survey results also began to establish that farmers were perceiving actual savings in irrigation time, labor and water, greater water control, uniform applied water distribution, and elimination of high and low spots in fields. The most recent survey, EWUP (1983c), showed that farmers are interested in continuing the use of EWUP's practices on their farms. This indicates that a level of understanding has been achieved and the benefits of the practices clearly demonstrated.

SUMMARY

This report has been a review of three important aspects of the precision land leveling (PLL) work in Abu Raya: a) a qualitative review of the K.S. Team experience in performing PLL operations in Abu Raya, i.e., how it was done, when, the need, who was involved, what constraints exist, etc.; b) a quantitative review of the technical PLL data such as earthwork volumes, machinery operation and times, estimated costs; c) a review of the impact PLL has had (as part of a package of practices) in improving farm water management in Abu Raya.

Rice is a major summer crop in Abu Raya and efficient water management for rice mandates the need for flat, level basins. Numerous grid surveys of fields in Abu Raya have established that the mean range in elevations for 90% of the fields is greater than or equal to three times the standard acceptable tolerance for level basin irrigation. PLL has been performed by the K.S. Team during three periods of the year: November - December for winter crops, March for cotton and May - June for maize and rice. PLL is not performed after a rice crop because the soil is too moist and soil compaction may result. Soil moisture is extremely low during the May - June and November - December (unless there has been rain) periods due to the length of time since the last irrigation. With the heavy clay soils, this caused some difficulty in working the soil. Soil fertility and profile (depth) and other characteristics were reviewed. Given the expected maximum cuts (15-20 cm) for PLL to dead level, no major problems related to fertility or soil texture are expected. Machinery requirements, manpower inputs and levels of expertise for performing PLL in Abu Raya were summarized. EWUP

Manual No. 8 (EWUP, 1982b) and a computer program (which follows Manual No. 8) for the HP 9825 computer for PLL data analysis (Ley, 1983) are discussed. Photos of PLL operations in Abu Raya are included in an appendix.

Technical PLL data (grid surveys, machinery operation time, maps, etc.) have been collected during several seasons in Abu Raya. Summaries of these data have been compiled for this report. Estimates of earthwork volumes based on only the initial grid survey and the difference between pre- and post- construction surveys were made. The mean estimated earthwork volume for Abu Raya fields based on results of the initial grid survey only was 59 m^3/Feddan. The measured mean (using both the initial and post- construction surveys) was about 36 m^3/Feddan. These volumes are very small relative to earthwork volumes for PLL in other areas of the world. Costs for PLL are estimated both on a cost per unit area and cost per unit-volume of cut basis. Estimated costs based on all of the farm machinery utilized and on the soil scraper and field plane only are compared. Farm machinery cost tables developed by EWUP in 1979 are the basis of these estimates. Earthwork volumes in Abu Raya are small. The inaccuracies involved in estimating earthwork volumes by the summation method used may possibly be a large percentage.

Review of the seasonal results included herein show that mean results on sites where a farm irrigation improvement program has been applied (which includes PLL) consistently exhibit increases in farm irrigation efficiency, water application efficiency and crop production, in addition to water savings, irrigation time savings and labor savings. It is noted that the program is not PLL alone, but includes farm irrigation design and farm water management input as conjunctive practices necessary for success. Also included in the program is crop production and management input, another important factor. Water table management and soil salinity management have been demonstrated through better water management. Salinity management has been aided by flooded rice cultivation, which provides adequate leaching.

Continued maintenance of PLL through smoothing (a recommended seasonal tillage operation once PLL is done) and input on irrigation design and farm water management are requirements for maintaining improved irrigation performance levels. Farmer response to the program has been evaluated. The general results show farmers are beginning to perceive the benefits of PLL as well as the benefits of farm machinery inputs in their operations.

CONCLUSIONS

As a result of the review provided in this report, the following conclusions concerning PLL are made:

1. Fields in Abu Raya are not level enough for efficient farm water management, especially for rice production.
2. The opportunity time for performing PLL on operating farms is constrained to the periods between harvests and plantings if production loss is not to be permitted. Soil moisture conditions after harvesting of crops are not optimum for soil tillage (in Abu Raya), increasing the difficulty in working the soil.
3. Soils in Abu Raya are deep and of uniform texture. The maximum depth of cut expected for the Abu Raya area is not constrained by characteristics such as fertility and salinity.
4. PLL performed after a rice crop may cause soil compaction as well as problems with machinery movement over the soil surface.
5. An engineer trained in PLL design and two technicians are necessary (as a minimum) for performing field grid surveys and technical data analysis on any given field.
6. A skilled (trained) farm machinery operator is necessary for PLL operations. Maximum efficiency in earthmoving (with soil scraper) and smoothing (with field plane or float) can be accomplished only with training and experience.
7. Equipment use and maintenance must be carefully monitored. A farm machinery engineer to oversee these aspects of PLL has worked well in Abu Raya.
8. PLL with laser systems has been used in Abu Raya and major advantages are the machinery maneuverability in the field (small fields, corners, narrow strips) and ease of bringing the required machinery (tractor, soil scraper) to and into the field. The laser system also reduced the time for leveling without sacrificing on the precision of the job. Disadvantage is high cost for laser system. These observations are limited by the one experience of using the system in Abu Raya.
9. Earthwork cut volumes are relatively small in Abu Raya indicating farm machinery time is expended mostly in making numerous passes over a field and in smoothing.

10. Maintenance of PLL, once a designed grade has been constructed, is a necessary seasonal soil tillage operation accomplished by smoothing. This is a common practice in the U.S.
11. PLL along with associated practices has proven to be effective over several seasons in improving farm water management through increased efficiencies; reduced water use; savings of labor and time for irrigation; improved crop yields; improved water table and soil salinity conditions.
12. The demonstration program in Kafr El Sheikh which emphasizes PLL, farm irrigation design, farm water management advice, crop production advice, etc. is an effective means for modifying farm layouts and eliminating surface drains for improved farm water management, ease of mechanization, improved crop production, etc.
13. Estimated costs for PLL are relatively high compared to costs reported elsewhere due to the large machinery time required but small earthwork volumes.
14. Farm machinery availability in Abu Raya is very limited. Appropriate machinery for PLL needs to be made available from an outside source such as the government or private contractors.
15. Professional personnel (engineers) trained in technical PLL design and analysis, technicians trained to provide effective assistance and skilled, well-trained farm machinery operators presently available in Egypt for doing PLL are limited. Training programs in PLL design and analysis and farm machinery use and operation for PLL can effectively minimize this constraint.

RECOMMENDATIONS

Based on the contents of this report, the following recommendations are made:

1. Precision land leveling (PLL), farm irrigation system design and teaching and advising farmers of improved farm water management techniques should be implemented as an integrated program to improve farm water management. Detailed economic feasibility analyses should be made to determine benefits and costs to farmers more accurately than those briefly described here. The technical feasibility of this program has been well-demonstrated in Kafr El Sheikh. The economic feasibility for the typical Egyptian farmer needs to be determined.

2. PLL must be made available either by the government through a subsidized program where machinery and trained personnel are provided, or by private enterprises which are developed with government assistance (i.e., to obtain machinery, provide loans to farmers, etc.).
3. Before any efficient large-scale PLL programs can be implemented, training programs for professional people (engineers) in technical aspects of PLL (design, analysis, construction), for technicians in field layout work, surveying, etc. and for farm machinery operators must be conducted. The training programs should be sufficiently broad to address the entire farm system for improvement including: design of farm irrigation systems, management of the systems for efficient use of water and cultural methods and practices for good crop production. Interdisciplinary teams such as EWUP's (in Minya, Mansuriya, and Kafr El Sheikh) are good role models of the teams that need to be developed to implement an improvement program along the lines suggested in this report.
4. The laser land leveling system used showed improved maneuverability in the field, improved ability for transporting PLL machinery (scraper only) to fields, similar precision and reduced time required for completing the job. Presently, however, the major capital expense in acquiring a laser system more than offsets these advantages for the conditions of Egyptian farmers. The observations given are also based on only one experience, therefore no definite conclusion or recommendation is given here.

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AMERICAN EQUIVALENTS OF EGYPTIAN ARABIC TERMS AND MEASURES COMMONLY USED IN IRRIGATION WORK

LAND AREA	IN SQ METERS	IN ACRES	IN FEDDANS	IN HECTARES
1 acre	4,046.856	1.000	0.963	0.405
1 feddan	4,200.833	1.038	1.000	0.420
1 hectare (ha)	10,000.000	2.471	2.380	1.000
1 sq. kilometer	100×10^4	247.105	238.048	100.000
1 sq. mile	259×10^6	640.000	616.400	259.000

WATER MEASUREMENTS	FEDDAN-CM	ACRE-FEET	ACRE-INCHES
1 billion m^3	23,809,000.000	810,710.000	
1,000 m^3	23.809	0.811	9.728
1,000 m^3 /Feddan (= 238 mm rainfall)	23.809	0.781	9.372
420 m^3 /Feddan (= 100 mm rainfall)	10.00	0.328	3.936

OTHER CONVERSION		METRIC	U.S.
1 ardab	=	198 liters	5.62 bushels
1 ardab/feddan	=		5.41 bushels/acre
1 kg/feddan	=		2.12 lb/acre
1 donkey load	=	100 kg	
1 camel load	=	250 kg	
1 donkey load of manure	=	0.1 m^3	
1 camel load of manure	=	0.25 m^3	

EGYPTIAN UNITS OF FIELD CROPS

CROP	EG. UNIT	IN KG	IN LBS	IN BUSHELS
Lentils	ardeb	160.0	352.42	5.87
Clover	ardeb	157.0	345.81	5.76
Broadbeans	ardeb	155.0	341.41	6.10
Wheat	ardeb	150.0	330.40	5.51
Maize, Sorghum	ardeb	140.0	308.37	5.51
Barley	ardeb	120.0	264.32	5.51
Cottonseed	ardeb	120.0	264.32	8.26
Sesame	ardeb	120.0	264.32	
Groundnut	ardeb	75.0	165.20	7.51
Rice	dariba	945.0	2081.50	46.26
Chick-peas	ardeb	150.0	330.40	
Lupine	ardeb	150.0	330.40	
Linseed	ardeb	122.0	268.72	
Fenugreek	ardeb	155.0	341.41	
Cotton (unginned)	metric qintar	157.5	346.92	
Cotton (lint or ginned)	metric qintar	50.0	110.13	

EGYPTIAN FARMING AND IRRIGATION TERMS

fara = branch
marwa = small distributer, irrigation ditch
masraf = field drain
mesqa = small canal feeding from 10 to 40 farms
qirat = cf. English "karat", A land measure of 1/24 feddan, 175.03 m^2
qaria = village
sahm = 1/24th of a qirat, 7.29 m^2
saqia = animal powered water wheel
sarf = drain (vb.), or drainage. See also masraf, (n.)

EGYPT WATER USE AND MANAGEMENT PROJECT

PROJECT TECHNICAL REPORTS

NO.	TITLE	AUTHOR
PTR#1	Problem Identification Report for Mansuriya Study Area, 10/77 to 10/78.	By: Egyptian and American Field Teams.
PTR#2	Preliminary Soil Survey Report for the Beni Magdul and El-Hammami Areas.	By: A. D. Dotzenko, M. Zanati, A. A. Abdel Wahed, & A. M. Keleg.
PTR#3	Preliminary Evaluation of Mansuriya Canal System, Giza Governorate, Egypt.	By: American and Egyptian Field Teams.
PTR#7	A Procedure for Evaluating the Cost of Lifting Water for Irrigation in Egypt.	By: H. Wahby, M. Quenemoen, and M. Helal.
PTR#9	Irrigation & Production of Rice in Abu Raya, Kafr El-Sheikh Governorate.	Compiled By: R. Tinsley.
PTR#10	Soil Fertility Survey in Kafr El-Sheikh, El Mansuriya and El-Minya Pilot Projects.	By: Zanati, Soltanpour, Mostafa, & Keleg.
PTR#11	Kafr El-Sheikh Farm Management Survey Crop Enterprise Budgets and Profitability Analysis.	By: M. Haider & F. Abdel Al.
PTR#12	Use of Feasibility Studies in the Selection and Evaluation of Pilot Studies for Alternative Methods of Water Distribution in Egypt.	By: R. McConnen, F. Abdel Al, M. Skold, and G. Ayad.
PTR#13	The Role of Rural Sociologists in an Interdisciplinary, Action-Oriented Project: An Egyptian Case Study.	By: J. Layton and M. Sallam.
PTR#15	Village Bank Loans to Egyptian Farmers.	By: G. Ayad, M. Skold, and M. Quenemoen.

NO.	TITLE	AUTHOR
PTR#18	Population Growth and Development in Egypt: Farmers' and Rural Development Officials' Perspectives.	By: M. Sallam, E.C. Knop and S.A. Knop.
PTR#19	Effective Extension for Egyptian Rural Development: Farmers' and Officials' Views on Alternative Strategies.	By: E.C. Knop, M. Sallam, and S.A. Knop.
PTR#20	The Rotation Water Distribtuion System vs. The Continual Flow Water Distribution System.	By: M. El-Kady, J. Wolfe and H. Wahby.
PTR#21	El-Hammami Pipeline Design.	By: Fort Collins Staff Team.
PTR#22	The Hydraulic Design of Mesqa 10, An Egyptian Irrigation Canal.	By: W.O. Ree, M. El-Kady, J. Wolfe, and W. Fahim.
PTR#23	Farm Record Summary and Analysis for Study Cases at Abyuha, Mansuriya and Abu Raya Sites, 79/80.	By: F. Abdel Al, and M. Skold.
PTR#24	Agricultural Pests and Their Control.	By: E. Attalla.
PTR#26	Social Dimensions of Egyptian Irrigation Patterns.	By: E.C. Knop, M. Sallam, S.A. Knop and M. El-Kady.
PTR#28	Economic Evaluation of Wheat Trials at Abyuha, El-Minya Governorate. Winter 79/80-80/81 in Awad.	By: N. Farrag and E. Sorial.
PTR#29	Irrigation Practices Reported by EWUP Farm Record Keepers.	By: F. Abdel Al, M. Skold and D. Martella.
PTR#30	The Role of Farm Records in the EWUP Project.	By: F. Abdel Al and D. Martella.
PTR#35	Farm Irrigation System Design.	By: T.W. Ley.

NO.	TITLE	AUTHOR
PTR#36	Discharge and Mechanical Efficiency of Egyptian Water-Lifting Wheels.	By: R. Slack, H. Wahby and W. Clyma.
PTR#37	Allocative Efficiency and Equity of Alternative Methods of Charging for Irrigation Water: A Case Study in Egypt.	By: R. Bowen and R. Young.

EYGPT WATER USE AND MANAGEMENT PROJECT

MANUALS

NO.	TITLE	AUTHOR
MAN.#1	Trapezoidal Flumes for the Egypt Water Use Project.	By: A. R. Robinson.
MAN.#2	Programs for the HP Computer Model 9825 for EWUP Operations.	By: M. Helal, D. Sunada, J. Loftis, M. Quenemoen, W. Ree, R. McConnen, R. King, A. Nazr and R. Stalford.

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APPENDICES

Appendix A:

Photos of precision land leveling

operations in Abu Raya

Figure A1. Engineer and technicians perform a grid survey for PLL design in Abu Raya.

Figure A2. EWUP PLL operations in Abu Raya included removal of field drains. Here plowing of drain banks is being done.

Figure A3. A disk harrow was used here to break down the soil surface aggregates before soil scraping.

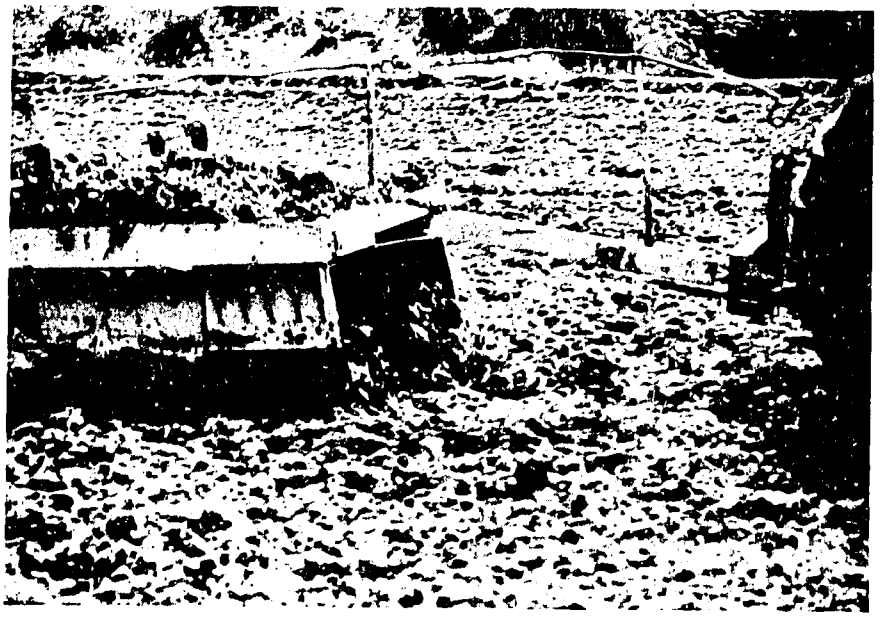


Figure A4. This soil scraper, fabricated in Egypt, was used for earthmoving operations in Abu Raya.

Figure A5. Soil is moved from high to low spots with the soil scraper. The soil scraper was also often used for smoothing in Abu Raya.

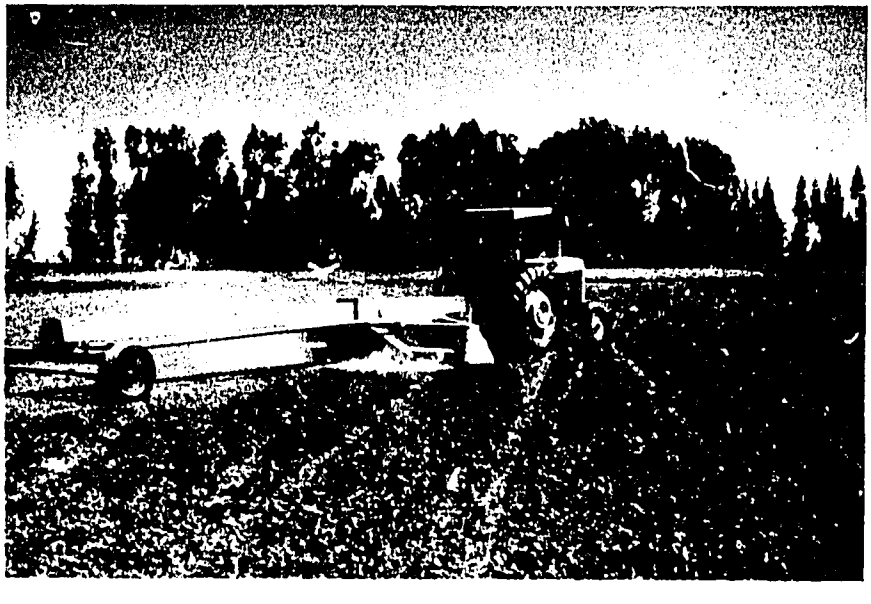


Figure A6. The field plane is used for final smoothing to bring fields in Abu Raya within ± 2 cm of the mean field elevation.

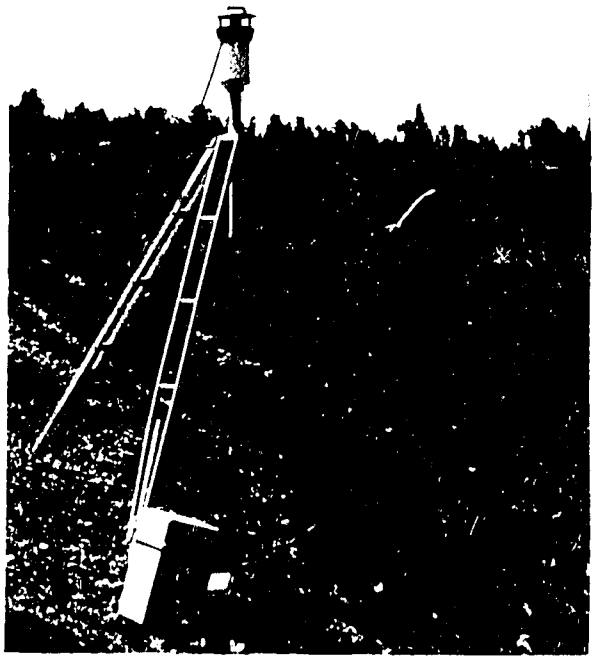
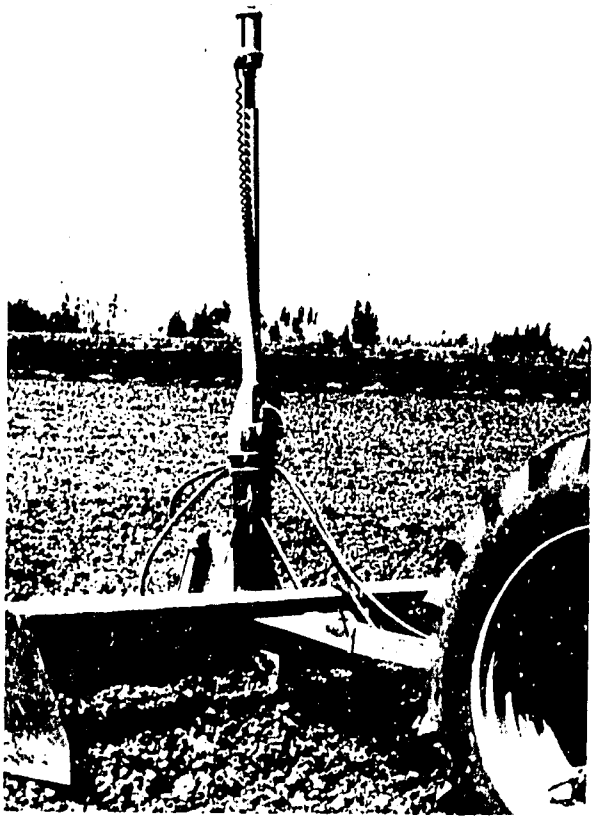


Figure A7. The latest technology, laser land leveling, has been used by EWUP in Abu Raya. Here the laser transmitter operating off a 12-volt car battery is mounted on a tripod. It is adjusted to emit a true horizontal plane.

Figure A8. The laser receiver is mounted on a mast on the soil scraper and is connected to the hydraulic controls of the tractor for automatic operation of the soil scraper blade elevation.



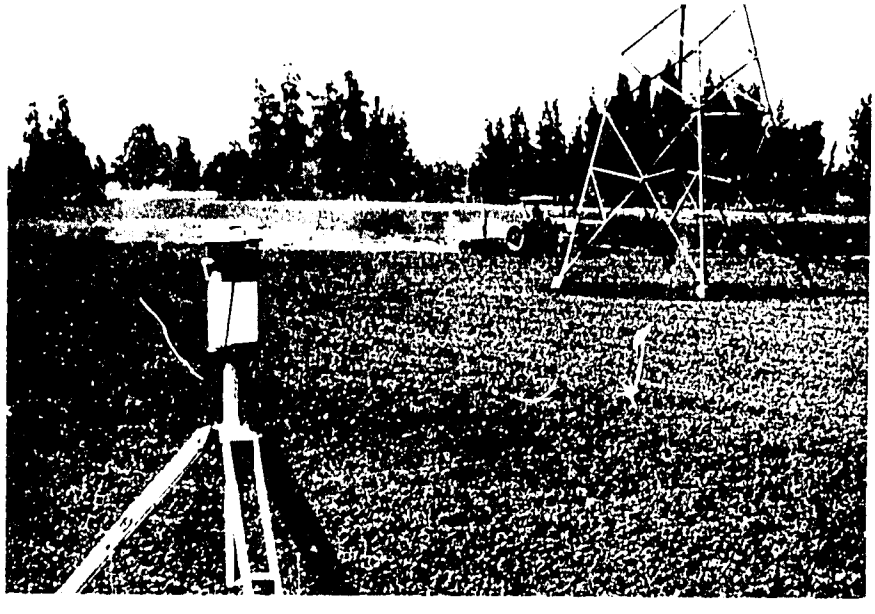


Figure A9. The operator drives over the field watching a monitor, which indicates if the field level is within a given tolerance, normally ± 1 cm.

APPENDIX B

Tables of Summary PLL Data for Abu Raya for the following seasons:

1) 1979 - 1980 Winter
2) 1980 - 1981 Winter
3) 1981 - Summer
4) 1981 - 1982 Winter

Summary tables include farm machinery hours (hrs/area and hrs/Feddan); farm machinery costs (LE/Feddan); summary of estimated earthwork volumes (m^3-cut, m^3-fill, m^3Feddan-cut); and estimated costs (LE/m^3-total farm machinery use basis and LE/m^3 - scraper and field plane use basis).

Note: 1980 Summer season PLL Data are not available.

Table B 1. Estimated farm machinery costs for (a) management land Preparation practices (per one feddan basis).

Kafr El-Sheikh

1979-1980 Winter season field trails

Implement (Estimated annual working hours)	Estimated total cost per hour (LE) (Tractor plus Implement***)	Site														Average	
		3-08		3-09 (1)		3-09 (2)		3-10		3-11		3-12		3-02			
		Hours	(LE)	Hours	(LE)	Hours	(LE)	Hours	(LE)	Hours	(LE)	Hours	(LE)	Hours	(LE)	Hours	(LE)
Chisel Plow (200)	2.745	2.80*	7.69	2.24	6.15	2.92	8.02	3.73*	10.24	2.04*	5.60	5.03*	13.81	3.50	9.61	3.18	8.73
Disk (200)	2.761	1.36	3.75	0.97	2.68	1.11	3.06	4.13	11.40	1.45	4.00	2.42	6.68	4.36	12.04	2.26	6.23
Scraper (200)	2.864	4.35	12.46	0.97	2.78	2.50	7.16	4.64	13.29	2.85	8.16	8.70	29.92	4.00**	11.46	4.00	11.46
Field Plane (100)	4.227	1.22	5.16	1.28	5.41	1.11	4.69	1.34**	5.66	0.60	2.54	0.61	2.58	1.86	7.86	1.34	5.66
Grader (Filling drain and making dikes) (100)	2.819	0.27	0.76	0.64	1.80	1.39	3.92	0.83	2.34	0.35	0.99	1.21	3.41	2.00	5.64	0.96	2.71
TOTAL		10.00	29.82	10.32	18.82	9.03	26.85	14.67	42.93	7.29	21.29	17.97	51.40	15.72	46.61	11.74	34.79

* Estimated from averages at other sites.

** Data not available, value is estimated as average at other sites.

*** From farm machinery cost tables. Tractor hourly cost = LE 2.412 (1000 hours per year).

Table B 2. Estimated earthwork volumes and associated estimated costs.

Kafr El-Sheikh

1979-1980 Winter Season

Site	Area (F)	Est. Cut Volume 1/ (m^3)	Est. Cut Volume 1/ (m^3/Fed.)	Est. Fill Volume 2/ (m^3)	Cut/Fill Ratio	Estimated Costs (LE/Fed) 3/ Total Farm Machinery	Estimated Costs (LE/Fed) 3/ Scraper and Field Plane	Estimated Costs (LE/m^3) Total Farm Machinery	Estimated Costs (LE/m^3) Scraper and Field Plane
3-08	1.26	48.70	38.65	33.66	1.45	29.82	17.62	0.77	0.46
3-09(1)	0.42	16.08	38.29	10.20	1.58	18.82	8.19	0.49	0.21
3-09(2)	1.18	42.15	35.72	26.40	1.60	26.85	11.85	0.75	0.33
3-10	0.70	29.05	41.50	21.44	1.35	42.93	18.95	1.03	0.46
3-11(1) 4/	0.76	-	-	-	-	21.29	10.70	-	-
3-11(2) 4/	0.73	-	-	-	-			-	-
3-12	1.58	86.18	54.54	57.54	1.50	51.40	37.50	0.94	0.60
3-02(1)	2.25	163.40	72.62 ↓ (ave. = 83.86) ↑	106.00	1.54	46.61	19.32	0.56	0.23
3-02(2)	1.35	128.4	95.11	98.00	1.31				
Mean (± std. dev.)			53.78 (±22.4)			33.96 (±12.92)	17.02 (±8.10)	0.76 (±0.21)	0.38 (±0.15)

1/ Cut volume based on survey before scraping if available or survey before planing in one case.

2/ Includes estimated volume required to fill the field drains which were removed.

3/ From Table B1.

4/ Survey data before leveling not available.

Table (B 3): Summary of farm machinery hours for pilot farms, Winter 1980-81 seas . (Not all operations were done on all sites).

Implement	Site																				Mean
	3-10				3-22		3-21		3-19						3-02						
	(A)		(B)						(A)		(B)		(C)		(A)		(B)		(C)		
	hr/area	hr/F	hr/area	hr/F	hr/area	hr/F	hr/area	hr/F	hr/area	hr/F	hr/area	hr/F	hr/area	hr/F	hr/area	hr/F	hr/area	hr/F	hr/area	hr/F	hr/F
Plow	0.63	0.66	0.88	0.48	1.75	0.76	2.13	0.41	--	--	--	--	1.75	0.88	2.25	1.76	3.39	1.75	--	--	0.96
Grader	0.63	0.66	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.66**
Disk	1.00	1.05	0.63	0.34	--	--	--	--	1.75	0.92	2.13	2.17	1.76	0.88	8.5	4.88	4.13	2.13	1.13	2.05	1.80
Scraper	1.13	1.19	5.38	2.92	6.100	2.61	19.51	3.75	9.51	5.01	1.13	1.15	12.63	6.35	2.75	2.15	7.00	3.61	2.75	5.00	3.37
Field Plane	0.30	0.32	0.58	0.32	--	--	--	--	3.63	1.91	1.63	1.66	1.50	0.75	--	--	1.13	0.89	--	--	0.98
Border/Ridger	0.08	0.08	0.17	0.09	0.5	0.22	0.38	0.07	0.63	0.33	0.38	0.39	0.63	0.32	--	--	0.25	0.13	--	--	0.20
Ditcher	--	--	--	--	--	--	0.25	0.05	2.38	1.25	--	--	0.25	0.13	0.25	0.20	0.25	0.13	--	--	0.35
Furrow Opener	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.25	0.98	--	--	0.75	1.36	1.17

3-10-A : Abdel Halim Zaid, Area = 0.95 F
3-10-B : Abdel Naby, Area = 1.84 F
3-22 : Abo Atia, Area = 2.30 F
3-21 : Abo Ismail, Area = 5.2 F
3-19-A : Soliman & Abo Yazid, Upper 1/3, Area = 1.90 F
3-19-B : " " " , Middle 1/3, Area = 0.98 F
3-19-C : " " " , Lower 1/3, Area = 1.99 F
3-02-A : Abdel Baki Site, Sugar Beets, Area = 1.28 F
3-02-B : " " " , Wheat, Area = 1.94 F
3-02-C : " : " , Onion, Area = 0.55 F
* : Ahmed and Sayed A. Baki only area = 1.27 F
** : Only 1 observation.

Table (B 4): Winter season 1980-81 estimated farm machinery costs per Feddan, Kafr El-Sheikh

Implement (Estimated annual working hours)[1]	Estimated Total cost per hour (LE)[2]	Site										Mean
		3-10		3-22	3-21	3-19			3-02			
		A	B			A	B	C	A	B	C	
Chisel Plow (200)	2.745	1.81	1.32	2.09	1.13	--	--	2.42	4.83	4.80	--	2.63
Disk (200)	2.761	2.90	0.94	--	--	2.54	5.99	2.43	13.47	5.88	5.66	4.98
Scraper (200)	2.864	3.41	8.36	7.48	10.74	14.35	3.29	18.19	6.16	10.34	14.32	9.66
Field Plane (100)	4.227	1.35	1.35	--	--	8.07	7.02	3.17	--	3.76	--	4.12
Border/Ridger (50)	3.210	0.26	0.29	0.71	0.22	1.06	1.25	1.03	--	0.42	--	0.65
Furrower (100)	2.705	--	--	--	--	--	--	--	2.65	--	3.68	3.16
Ditcher (100)	2.948	--	--	--	0.15	3.6[illegible]	--	0.38	0.59	0.38	--	1.04
Grader (100)	2.819	1.86	--	--	--	--	--	--	--	--	--	1.86
Total		11.59	12.26	10.28	12.24	29.71	17.55	27.62	27.70	25.58	23.66	28.10[3]

1/ Estimated annual use from EWUP farm machinery tables (same as used for 1979-80 data).

2/ Estimated total hourly cost (tractor + implement) from EWUP farm machinery tables (same as used for 1979-80 data). Tractor use estimated at 1000 hours/year at LE 2.412/hour

3/ Total cost per feddan for all operations. For the first five operations (the most common for wheat land preparation) the total is LE 22.04 per feddan.

Table (B 5): Estimated earthwork volumes and associated estimated costs. 1980-81 Winter season. Kafr El-Sheikh

Site	Area (F)	Estimated Cut Volume[1/] (m^3)	Estimated Cut Volume[1/] (m^3/Fed)	Estimated Fill Volume[2/] (m^3)	Cut/Fill Ratio	Estimated Costs (LE/Fed)[3/] Total Farm Machinery	Estimated Costs (LE/Fed)[3/] Scraper & Field Plane	Estimated Costs (LE/m^3) Total Farm Machinery	Estimated Costs (LE/m^3) Scraper & Field Plane
3-10-A	0.94	72.8	77.5	71.3	1.02	11.59	4.76	0.15	0.06
3-10-B	1.84	146.1	79.4	134.3	1.09	12.26	9.71	0.15	0.12
3-22	2.30	432.0	187.8	288.5	1.50	10.28	7.48[4/]	0.05	0.04
3-21	3.03	253.0	83.5	207.0	1.22	12.24	10.74[4/]	0.15	0.13
3-02-A	1.28	97.0	75.8	71.0	1.37	27.70	6.16[4/]	0.37	0.08
3-02-B	1.94	153.0	78.9	112	1.37	25.58	14.10	0.32	0.18
3-19-A	1.90	96.8	51.0	74.8	1.29	29.71	22.42	0.58	0.44
3-19-B	0.97	50.2	51.8	39.6	[illegible]27	17.55	10.31	0.34	0.20
3-19-C	1.99	103.0	51.8	68.0	1.51	27.62	21.36	0.53	0.41
Mean (± std. dev.)			81.9 (±41.9)			19.39 (±8.15)	11.89 (±6.30)	0.29 (±0.18)	0.18 (±0.15)

1/ Cut volume based on survey before scraping.

2/ Includes estimated required fill volume for drain removal.

3/ From Table B4.

4/ Scraper only, field plane could not be brought to field.

Table (B 6): Summary of farm machinery hours for Hammad pilot farms, cotton crop, summer season, 1981.

Implement	Site																		S.D. / Mean = CV
	3-01										3-20		3-02						
	(A)		(B)		(C)		(D)		(E)				(A)		(B)		(C)		
	hr/area	hr/F	hr/area	hr/F	hr/area	hr/F	hr/area	hr/F	hr/area	hr/F	hr/area	hr/F	hr/area	hr/F	hr/area	hr/F	hr/area	hr/F	hr/F
Plow	2.20	2.37	1.72	1.13	9.20	2.46	2.05	2.23	1.55	1.60	5.58	1.25	1.58	0.61	0.30	0.65	3.58	3.03	0.86/1.70 = 0.51
Grader (f.d. elimination)	--	--	--	--	2.25	0.60	--	--	--	--	--	--	--	--	--	--	--	--	-----
Scraper	2.75	2.96	4.17	2.74	10.90	2.91	1.75	1.90	2.12	2.19	16.50	3.68	5.25	2.04	1.50	3.26	3.17	2.69	0.58/2.71 = 0.22
Field Plane	1.00	1.08	1.17	0.77	3.45	0.92	--	--	--	--	3.00	0.67	2.17	0.84	--	--	--	--	0.16/0.86 = 0.18
Furrower	0.70	0.75	0.45	0.30	2.50	0.67	0.42	0.46	0.45	0.46	2.50	0.56	1.00	0.39	--	--	1.17	0.99	0.22/0.57 = 0.39
Ditcher	0.18	0.19	0.15	0.10	0.50	0.13	--	--	0.15	0.15	0.58	0.13	--	--	--	--	--	--	0.03/0.14 = 0.24

3-01-A : Ibrahim Shams El-Din, Area = 0.93 F
-B : Marie Marie Yusef, Area = 1.52 F
-C : Seria M. Abdo, Area = 3.74 F
-D : Hamed El-Behery, Area = 0.92 F
-E : Abdel Hamid Shaban, Area = 0.97 F

3-20 : Soliman El-Said Soliman, Area = 4.48 F

3-02-A : Ahmed Abdel Baki and Ragab Abdel Baki, Area = 2.57 F
-B : Hanem El-Assiby, Area = 0.46 F
-C : Bassiuni El-Ghanam, Area = 1.18 F

Table (B 7): Summary of farm machinery hours for Manshia pilot farms, cotton crop, summer season, 1981.

Implement	Site																		S.D. / Mean = CV
	3-10						3-22				3-23				3-24				
	(A)		(B)		(C)		(A)		(B)		(A)		(B)		(A)		(B)		
	hr/area	hr/F	hr/area	hr/F	hr/area	hr/F	hr/area	hr/F	hr/area	hr/F	hr/area	hr/F	hr/area	hr/F	hr/area	hr/F	hr/area	hr/F	hr/F
Plow	0.83	0.87	0.88	o.77	0.27	0.66	0.83	0.39	--	--	0.50	0.68	3.50	1.98	0.82	0.31	0.50	1.00	0.52 / 0.83 = 0.62
Grader (f.d. elimination)	--	--	--	--	--	--	1.10	0.51	--	--	--	--	--	--	--	--	--	--	----------
Scraper	3.18	3.35	2.07	1.80	0.90	2.20	8.12	3.79	4.15	3.49	2.42	3.27	4.92	2.78	5.53	2.09	1.13	2.26	0.72 / 2.78 = 0.26
Field plane	1.13	1.19	1.02	0.89	0.20	0.49	--	--	--	--	--	--	--	--	--	--	--	--	0.35 / 0.86 = 0.41
Furrower	0.92	0.97	0.75	0.65	0.30	0.73	1.78	0.83	1.00	0.84	0.63	0.85	0.75	0.42	1.88	0.71	0.32	0.64	0.16 / 0.74 = 0.22

3-10-A : Abdel Halim Zaid, Area = 0.95 F

-B : Khadra Zaid, Area = 1.15 F

-C : Om'Ahmed (Ali Zaid), Area = 0.41 F

3-22-A : Mohey Abo Atia, Area = 2.14 F

-B : Abdel Fattah Abo Atia, Area = 1.19 F

3-23-A : Ismail Abo Diab, Area = 0.74 F

-B Abdalah Awad, Area = 1.36 F

Abdel Aziz Awad, Area = 0.41 F Total 1.77 F

3-24-A : El-Shawatfi, Area = 2.65 F

-B : Mohamed Helal, Area = 0.50 F

Table (B 8): Summer season 1981 cotton crop farm machinery costs per feddan, Kafr El-Sheikh

Implement (Est. annual Working hours)[1/]	Est. Total hourly cost (LE)[2/]	Site (LE/Feddan) 3-10 A	3-10 B	3-10 C	3-22 A	3-22 B	3-23 A	3-23 B	3-24 A	3-24 B	3-01 A	3-01 B	3-01 C	3-01 D	3-01 E	3-20	3-02 A	3-02 B	3-02 C	Mean
Chisel plow(200)	2.745	2.39	2.11	1.81	1.07	--	1.87	5.44	0.85	2.25	6.51	3.10	6.75	6.12	4.39	3.43	1.67	1.78	8.32	3.55
Scraper (200)	2.864	9.59	5.16	6.30	10.85	10.00	9.37	7.96	5.99	6.47	8.48	7.85	8.33	5.44	6.27	10.54	5.84	9.34	7.70	7.86
Field plane(100)	4.227	5.03	3.76	2.07	--	--	--	--	--	--	4.57	3.25	3.89	--	--	2.83	3.55	--	--	3.62
Furrower (100)	2.705	2.62	1.76	1.97	2.25	2.27	2.30	1.14	1.92	1.73	2.03	0.81	1.81	1.24	1.24	1.51	1.05	--	2.68	1.78
Grader (100)	2.819	--	--	--	1.44	--	--	--	--	--	--	--	1.69	--	--	--	--	--	--	1.56
Ditcher (100)	2.948	--	--	--	--	--	--	--	--	--	0.56	0.29	0.38	--	0.44	0.38	--	--	--	0.41
Total		19.63	12.79	12.15	15.61	12.27	13.54	14.54	8.76	11.85	22.15	15.30	22.85	12.80	12.34	18.89	12.11	11.12	18.70	18.78 [3/]

1/ Estimated annual use from EWUP farm machinery tables (same as used for 1979-80 winter season data and 1980-81 winter season data).

2/ Estimated total hourly cost (tractor + implement) from EWUP farm machinery tables.
Tractor use estimated at 1000 hours/year at LE 2.412 / hour.

3/ Mean total cost per feddan for all operations. For 1st four operations, the mean total cost is LE 16.86 per feddan. The mean total cost per feddan based on what operations were done at each farm is LE 14.79/feddan.

Table (B 9): Estimated earthwork volumes and associated estimated costs. 1981 Summer season, cotton crop. Kafr El-Shiekh

Site	Area (F)	Estimated Cut Volume[1/] (m^3)	Estimated Cut Volume[1/] (m^3/Fed)	Estimated Fill Volume[2/] (m^3)	Cut/Fill Ratio	Estimated Costs (LE/Fed)[3/] Total Farm Machinery	Estimated Costs (LE/Fed)[3/] Scraper & Field Plane	Estimated Costs (LE/m^3) Total Farm Machinery	Estimated Costs (LE/m^3) Scraper & Field Plane
3-10-A	0.95	66.0	69.5	40.0	1.65	19.63	14.62	0.28	0.21
3-10-B	1.15	64.0	55.7	45.0	1.42	12.79	8.92	0.23	0.16
3-10-C	0.41	16.0	39.0	12.0	1.33	12.15	8.37	2.31	0.21
3-22-A	2.14	2.39	111.7	195.0	1.23	15.61	10.85[4/]	0.14	0.10
3-22-B	1.19	108.0	90.8	77.0	1.40	12.27	10.00[4/]	0.14	0.11
3-23-A	0.74	39.0	52.7	35.5	1.10	13.54	9.37[4/]	0.26	0.18
3-24-A[5/]	1.59	35.6	22.4	30.7	1.16	8.41	4.90[4/]	0.38	0.22
3-24-B	0.50	18	36.0	16.5	1.10	11.85	6.47[4/]	0.33	0.18
3-01-A	0.93	67.2	72.3	37.3	1.55	22.15	13.05	0.31	0.18
3-01-B	1.52	88.0	57.9	68	1.30	15.30	11.10	0.26	0.19
3-01-C	3.74	187.7	50.19	147.4	1.27	22.85	12.22	0.46	0.24
3-01-D	0.92	45.8	49.8	33.8	1.35	12.80	5.44[4/]	0.26	0.11
3-01-E	0.97	57.9	59.7	47.7	1.21	12.34	6.27[4/]	0.21	0.11
3-20	4.48	178.7	39.9	153.1	1.17	18.89	13.37	0.47	0.34
Mean (± std. dev.)			57.7 (±23.0)			15.04 (±4.28)	9.64 (±3.09)	0.29 (±0.10)	0.18 (±0.06)

1/ Estimated cut volume based on initial field survey.

2/ Estimated fill volume includes required fill volume for removing ditches (if any).

3/ From Table B8.

4/ Scraper only. Field Plane could not enter field.

5/ Survey data for part of site not available, cost figures adjusted to area with available data.

Table (B10) Summary of farm machinery hours for K.S. pilot farms, maize crop, Summer season, 1981.

Implement	Site					
	3-10 (Manshia)				3-01 (Hammad)	
		A	B			
	hr/area	hr/Fed	hr/area	hr/Fed	hr/area	hr/Fed
Plow	1.75	2.43	0.63	1.19	1.25	0.83
Grader	0.75	1.04	--	--	--	--
Scraper	1.62	2.25	0.25	0.47	5.50	3.67
Field plane	--	--	--		2.75	1.83
Furrower	0.50	0.69	1.12	2.11	0.37	0.25

3-10-A: Om' Ahmed Zaid, Area= 0.72 Fed.

-B: Khadra Zaid, Area= 0.53 Fed.

3-01 : Abo Issa, Area= 1.5 Fed.

Table (B11) Summary of farm machinery hours for K.S. pilot farms, rice crop, summer season, 1981.

Implement	Site							
	3-22 (M)		3-10 (M)		3-25 (M)		3-01 (H)	
	hr/area	hr/Fed.	hr/area	hr/Fed.	hr/area	hr/Fed.	hr/area	hr/Fed
Plow	--	--	--	--	--	--	1.75	0.83
Grader	--	--	--	--	1.5	0.35	0.75	0.36
Scraper	5.25	2.1	5.25	5.52	12.87	2.99	10.43	4.97
Field plane	--	--	--	--	--	--	1.00	0.48
Border/Ridger	0.5	0.2	0.12	0.13	0.25	0.06	0.25	0.12

3-22: Mohey Abo Atia, area = 2.5 Fed.

3-10: Abdel Halim Zaid, area = 0.95 Fed.

3-25: Shenawia site area = 4.3 Fed.

3-01: Seria M. Abdo, area = 2.1 Fed.

Table (B12) Summer season 1981 Rice, Maize crops farm machinery costs per feddan. Kafr El-Sheikh

Implement (Est. annual (1) working hours)	Est. Total hourly Cost (2) (L.E)	Sites (L.E/Feddan) Rice 3-22 (M)	Rice 3-10 (M)	Rice 3-25 (M)	Rice 3-01 (H)	Rice Mean	Corn 3-10(M) A	Corn 3-10(M) B	Corn 3-01(H)	Corn Mean
Chisel plow (200)	2.745	--	--	--	2.278	2.278	6.670	3.267	2.278	4.072
Scraper (200)	2.864	6.014	15.809	8.563	14.234	11.155	6.440	1.346	10.511	6.099
Field plane(100)	4.227	--	--	--	2.029	2.029	--	--	7.735	7.735
Furrower (100)	2.705	--	--	--	--	--	1.866	5.708	0.676	2.750
Grader (100)	2.819	--	--	0.987	1.015	1.001	2.932	--	--	2.932
Border/ridger (50)	3.210	0.642	0.417	0.193	0.385	0.409	--	--	--	--
Total		6.656	16.226	9.763	19.641	16.872 (3)	17.908	10.321	21.200	23.587 (3)

(1) Estimated annual use from EWUP farm machinary tables (same as used for 1979-80 winter season data and 1980-81 winter season data).

(2) Estimated total hourly cost (tractor + implement) from EWUP farm machinary tables.

(3) Mean total cost per feddan for all operations. The mean total cost per feddan based on what operations were done at each farm is LE. 13.15 for rice and LE 16.48 for corn.

Table (B 13): Estimated earthwork volumes and associated estimated costs. 1981 Summer season, Rice and Maize crops. Kafr El-Sheikh

Site	Area (F)	Estimated Cut Volume 1/ (m^3)	Estimated Cut Volume 1/ (m^3/Fed)	Estimated Fill Volume 2/ (m^3)	Cut/Fill Ratio	Estimated Costs (LE/Fed) 3/ Total Farm Machinery	Estimated Costs (LE/Fed) 3/ Scraper & Field Plane	Estimated Costs (LE/m^3) Total Farm Machinery	Estimated Costs (LE/m^3) Scraper & Field Plane
RICE									
3-10 4/	--	--	---	--	---	---	---	---	---
3-22 5/	2.5	78	31.2	67	1.16	6.66	6.01 6/	0.21	0.19
3-25	4.3	137.5	32.0	106.0	1.30	9.76	8.56 6/	0.31	0.27
3-01	2.1	100.0	47.6	93.6	1.07	19.64	16.26	0.41	0.34
Mean (±std. dev.)(3-25 & 3-01 only)			39.8 (±11.0)			14.70 (± 6.99)	12.41 (± 5.44)	0.36 (±0.07)	0.31 (±0.05)
MAIZE									
3-10-A	0.72	31.0	43.1	23.0	1.35	17.91	6.44 6/	0.42	0.15
3-10-B	0.53	21.0	39.6	16.0	1.30	10.32	1.35 6/	0.26	0.03
3-01	1.50	110.4	74.1	79.5	1.39	21.2	17.75	0.29	0.24
Mean (std. dev.)			52.3 (±19.0)			16.48 (± 5.58)	8.35 (±8.12)	0.32 (±0.09)	0.14 (±0.11)

1/ Based on initial grid survey
2/ Includes required fill volume, if any, for drain removal.
3/ From Table B12.
4/ 3-10 Survey Data not available
5/ Second time for PL.
6/ Scraper only. Field Plane could not enter field.

Table(B14): Summary of farm machinery hours for Hammad and Manshia pilot farms. 1981/82 Winter Season

Implement	Sites														
	3-20(H)		3-26(H)				3-10(M)				3-27(M)				±
			A		B		A		B		A		B		(Std.dev.)
	hr/area	hr/Fed	hr/area	hr/Fed	hr/area	hr/Fed	hr/area	hr/Fed	hr/area	hr/Fed	hr/area	hr/Fed	hr/area	hr/Fed	hr./Fed
Old marwa and field drain Elim. (Chisel plow, g[illegible])	--	--	0.63	0.31	1.38	0.52	--	--	--	--	2.75	1.43	0.25	0.14	0.60(±0.6)
Chisel plow	3.25	0.73	1.50	1.34	4.13	1.56	--	--	--	--	2.50	1.30	3.50	1.91	1.37(±0.43)
Soil Scraper	--	--	8.13	3.97	13.50	5.11	--	--	--	--	16.25	8.46	12.00	6.56	6.03(±1.94)
Field plane	16.50	3.68	2.63	1.28	2.75	1.04	4.13	4.30	2.63	2.12	7.13	3.71	2.88	1.57	2.53(±1.34)
Furrows	2.5	0.56	1.13	0.55	4.00	1.52	--	--	--	--	0.38	0.20	0.38	0.21	0.61(±0.54)
Ditcher	0.25	0.06	0.13	0.06	0.13	0.05	--	--	0.13	0.10	0.38	0.20	--	--	0.09(±0.06)
Border	0.13	0.03	0.25	0.12	--	--	0.13	0.14	--	--	0.38	0.20	--	--	0.08(±0.06)

3-20	Soliman El Said Soliman,	Area = 4.48 Fed	(Previous site, 2nd time for leveling)
3-26-A	Abo El Yazid Soliman,	Area = 2.05 Fed	
B	Ahmed Elzizi,	Area = 2.64 Fed	
3-10-A	Abd El-Halim Zaid,	Area = 0.96 Fed	(Previous site, 2nd time for leveling)
-B	Khadra Zaid,	Area = 1.24	(Previous site, 2nd time for leveling)
3-27-A	El Said Baraka,	Area = 1.92	
-B	Mahmoud Baraka,	Area = 1.83	

Table (B15) Winter season 1981/1982 estimated farm machinery cost per feddan, Kafr El-Sheikh

Implement (1) (Estimated annual working hours)	Estimated Total cost[2] per hour (LE)	Sites (L.E./Feddan)							Mean
		3-20[4] (H)	3-26(H)		3-10[4] (M)		3-27(M)		
			A	B	A	B	A	B	
Grader (100)	2.819	--	0.874	1.466	--	--	4.031	0.395	1.692
Chisel plow (200)	2.745	2.004	3.678	4.282	--	--	3.569	5.243	3.755
Soil Scraper (200)	2.864	--	11.370	14.635	--	--	24.229	18.788	17.256
Field plane (100)	4.227	15.555	5.411	4.396	18.176	8.961	15.682	6.636	10.688
Furrower (100)	2.705	1.515	1.488	4.112	--	--	0.541	0.568	1.645
Ditcher (100)	2.948	0.177	0.177	0.147	--	0.297	0.590	--	0.278
Border Ridger (50)	3.210	0.096	0.385	--	0.449	--	0.642	--	0.393
Total		19.347	23.383	28.988	18.625	9.258	49.284	31.63	35.707(3)

(1) Estimatedannual use from EWUP farm machinery tables (Same as used for 1979/1980).

(2) Estimated total hourly cost (tractor + implement) from EWUP farm machinery tables. Tractor use estimated at 1000 hours/yearat LE. 2.412/hour.

(3) Mean total cost per feddan for all operations. The mean total cost per feddan based on what operations were done at each farm is LE 25.788.

(4) Sites 3-10 and 3-20 were levelled for summer season 1981 by EWUP farm machinery. The average total cost per feddan for farm machinery work for Winter season 1981-82 at these sites was L.E. 15.74. Average total cost per feddan for new sites was LE 33.32 Higher cost of land leveling for new sites is due in part to elimination of field drains.

Table (B 16): Estimated earthwork volumes and associated estimated costs. 1980-81 Winter season. Kafr El-Sheikh

Site	Area (F)	Estimated Cut Volume[1/] (m^3)	Estimated Cut Volume[1/] (m^3/Fed)	Estimated Fill Volume[2/] (m^3)	Cut/Fill Ratio	Estimated Costs (LE/Fed)[3/] Total Farm Machinery	Estimated Costs (LE/Fed)[3/] Scraper & Field Plane	Estimated Costs (LE/m^3) Total Farm Machinery	Estimated Costs (LE/m^3) Scraper & Field Plane
3-20[5]	4.48	164.0	36.6	86	1.9	19.35	15.56[4/]	0.53	0.43
3-26-A	2.05	119	58.1	98	1.21	23.38	16.78	0.40	0.29
3-26-B	2.64	190	72.0	100	1.9	28.99	19.02	0.40	0.26
3-10-A[5/]	0.96	29	30.2	16	1.81	18.63	18.18[4/]	0.62	0.60
3-10-B[5/]	1.24	38	30.7	31	1.23	9.26	8.96[4/]	0.30	0.29
3-27-A	1.92	195	101.6	151	1.29	49.28	39.90	0.49	0.39
3-27-B	1.83	83	45.4	76	1.09	31.63	25.41	0.70	0.56
mean (std. dev.)		New Sites	69.3 (±24.1)			33.32 (±11.18)	25.28 (±10.41)	0.50 (±0.14)	0.38 (±0.14)
		Old Sites	32.5 (± 3.6)			15.75 (± 5.63)	14.23 (± 4.75)	0.48 (±0.17)	0.44 (±0.16)

1/ Based on initial survey.

2/ Extra fill volume for dain removal included.

3/ From Table B15.

4/ Field Plane only, scraper not used.

5/ Second time for PLL.