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Evaluation of integrated surface irrigation management in the old lands

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ABSTRACT

The experimental fieldwork was conducted at the On-farm Irrigation Development Project in Sohag Governorate, Upper Egypt. The objectives of this work were to study the performance of the improved surface irrigation system and comparing it with the traditional surface irrigation system. The performance indicators were land losses, conveyance efficiency, irrigation time, application efficiency, filed water use efficiency and crop yield. Where the most important results could be summarized as follows: i) The saved agricultural land through using buried pipes as improved Mesqa ranged from about 2.74 % to 2.067 % and in the lining canal it ranged from1.33 % to 1.04 % compared with traditional earth Mesqa which were occupied by the channels and ridges. ii) Average conveyance efficiencies were as 82.4%, 92.7%, and 98.38% for traditional earthen, lining and buried pipes Mesqas respectively. iii) Average application efficiencies were 81.5 % under improved On-farm surface irrigation (Precession laser land leveling) compared with 59% under traditional surface irrigation. iv)Irrigation time decreased 31.39% by using improved surface irrigation compared with traditional surface irrigation. V)The productivity of wheat and sorghum increased 10.81% and 10.44 % respectively under improved surface irrigation compared with traditional surface irrigation.vi) the values of field water use efficiency (FWUE) for wheat and sorghum were 1.49 kg / m^3 and 1.08 kg / m^3under improved surface irrigation compared with 0.87 kg/m^3 and 0.631 kg / m^3 under traditional surface irrigation respectively.

INTRODUCTION

Water is one of the most important limited natural resources and it is essential substance for sustaining life on the earth. Water scarcity is a growing global problem; challenging sustainable development and constraining efforts to produce enough food to meet increasing food needs (Molden2007). During the last 50 years, the actual level of per capita water supply decreased significantly in Egypt due to population increase, drought, and inefficient water use. Irrigation water consumes about 80 % of the water budget for cultivating Approximately 7.1 million feddans with an annual cropping area of about 12 million feddans(El-Quosy, 2011). About 5.05 million feddans is old lands irrigated by surface irrigation methods (El-Berry et al, 2006).Therefore the agricultural and irrigation Egyptian policies have been working to improve surface irrigation system in the old lands through the national project On-Farm Irrigation Development in the Oldlands (OFIDO) for improving surface irrigation and increase the water use efficiency in the Egyptian old lands (MALR,2009).

the features of the national project (OFIDO) is improving the Mesqa delivery system this is accomplished by changing irrigation delivery system from earthen Mesqa with multiple lifting point to low pressure buried PVC pipelines with single lifting (pumping) point at the head of the Mesqa.As well as improving on farm conveyance system by changing from earthen Marwa to low pressure buried PVC pipelines and irrigate the field by using alfalfa valve. Establishment of Water Users Associations (WUA) for each individual Mesqa. The WUAs have the responsibility of operating and maintaining the Mesqas, laser land-leveling, deep ploughing and gypsum treatment. The main goal of this project is to improve on-farm irrigation systems in 5 million feddans in the Nile Delta and Valley during the action plan period (2011-2021) to save water for reclaiming the targeted areas in the 2030 strategic plan (El-Gendy, 2011).

This research aims to evaluate the applications of the national project (OFIDO) for improving the surface irrigation and increase the water use efficiency under integrated management conditions in order to, raise the water use efficiency and maximizing productivity and determining the ability of this national project to reduce water losses and raise the efficiency of surface irrigation system. The principal objective of evaluating surface irrigation systems is to identify management practices and system configurations that can be feasibly and effectively implemented to improve the irrigation efficiency.

MATERIALS AND METHODS

1-Experimental site

Field experimental works were conducted along two successive summer seasons of 2015 and 2016 in Upper Egypt at Sohag governorate – Monsha city at Nasser branch canal (26° 28'/ N, 31° 48' / E) in the On-Farm Irrigation Development in the Oldlands (OFIDO). Fig (1) shows the sketch of improved surface irrigation. The study was conducted to evaluate the improved surface irrigation system and their effects on field water use efficiency and yield as the base for integrated surface irrigation management in the old lands.

To evaluate the impact of improved surface irrigation in the old lands areas of 49 feddan from fields that has been irrigated by improved surface irrigation through (OFIDO) national project under supervisor of Ministry of Agriculture at Sohag Governorate were selected. In this area, land losses were determined through measuring the area of traditional Mesqa and maraw. Conveyance efficiency through buried pipes from branch canal to the field was calculated. The chosen field has length 145 m and width 18.5 m. in average field laser landleveling at slope 0.02 % was carried out as an important improvement activity field application efficiency and water use efficiency were measured.

To compare the improved surface irrigation system with non improved surface irrigation in the old lands area of 42 feddan has been irrigated by earthen Mesqa and earthen Marwa in Sohag Governorate were selected. In this area land losses were obtained from measuring the area of traditional Mesqa and maraw. As well as conveyance efficiency through traditional Mesqa and maraw from branch canal to the field was determined in traditional surface irrigation area. The chosen field length was 120 m and the width was 17.3 m .This field has been traditional landleveling. Application efficiency, distribution uniformity, productivity, irrigation time and field water use efficiency was determined as the main evaluation parameter to compare the improved and traditional surface irrigation system.

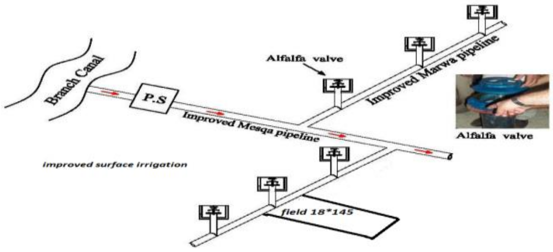


Fig. 1: Sketch of improved surface irrigation in area 49 feddan

2. Soil properties:

Physical analyses of the soil were determined according to the methods described by Abuzaid (2013). Soil particle size distribution was carried out using pipette method, which described by (Gee and Bauder, 1986). Soil bulk density (B.D) was measured according to (Black and Hartage, 1986). Soil moisture content at field capacity (F.C) and permanent wilting point (P.W.P) were measured according to (Walter and Gandener, 1986). Data are tabulated in Table (1).

Table 1. Physical and hydro-physical properties, at the experimental field

Depth (cm)	Physical properties					hydro-physical properties			
	Sand (%)		Silt (%)	Clay (%)	Textural Class	FC (%)	P.W.P (	AW (%)	B.D (gcm^{-3})
	Fine	Coarse							
0 – 40	14.8	3.4	39.5	42.3	**Clay**	52.6	25.7	26.9	1.23
40 – 70	15.1	3.5	39.2	42.2	**Clay**	52.4	25.7	26.7	1.24

F.C.: Field capacity W.P: Permanent wilting point AW: Available water B.D.: Bulk density

3- Field Crops in the study

Improved and traditional surface irrigation were evaluated on farmer's fields. Two fields were selected for two crops wheat (Seds12) in winter season and sorghum (Giza 15) in summer season where, wheat and sorghum are considering principle crops in the study area.

4-Description of improved surface irrigation

In improved surface irrigation under (OFIDO) project the field received irrigation water from the branch canal through electric pumping unit to the main and branch buried PVC pipes instead of traditional Mesqa and Marwa. The main line diameter ranged from 225mm to 280 mm and branch line diameter was 180 mm. The PVC pipes were connected together using faucet rubber ring jointing system. On branch line there is risers ended by 152mm alfaalfa valve in order to deliver irrigation water to land surface which was prepared by laser land leveling. Fig (2) shows components of main and branch lines in improved surface irrigation network.

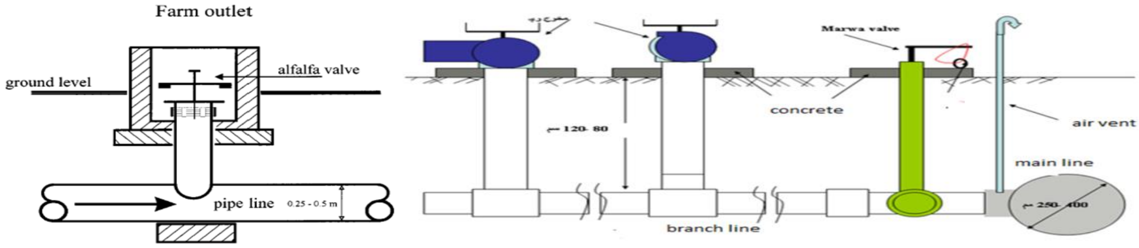


Fig. 2. Components of main and branch lines in improved surface irrigation network.

5-Traditional surface irrigation

In traditional surface irrigation the tertiary canals earthen Mesqas receive irrigation water by individual farmer's pumping units and traditional surface irrigation as showing in Fig (3) the pump lift irrigation water from the branch canal to convey irrigation water to earthen Marwa by gravity then to the field. The area served by a Mesqa is usually 20 to 100 feddan. Experimental measurements were conducted to measure land losses in Mesqa and Marwa, conveyance efficiency in traditional Mesqa, application efficiency in traditional landleveling field and water use efficiency.

Fig. 3: individual privet pumps and the earthen Mesqa in traditional surface irrigation

6- Land losses through traditional irrigated area:-

To calculate land losses area for earthen Mesqa, earthen Marwa, lining Mesqa and lining Marwa three different zones were surveyed. Fig. 4: and Fig.5: shows the cross section and dimensions measurement in traditional Mesqa. The total area of the zone was determined. Three cases of different areas 30,49and 96 feddan were chosen to determine land losses ratio in earthen Mesqa and lining Mesqa.To calculate the ratio between Mesqa area and the total area equation(1) and (2) was used.

$$Am = W_v * L \quad \ldots\ldots\ldots\ldots (1)$$

Where:

A_m = area of Mesqa m^2

L = length of Mesqa m.

W_v = average width of Mesqa m.

$$R = \frac{Am}{A} * 100 \quad \ldots\ldots\ldots\ldots (2)$$

Where:

R = the ratio between Mesqa area and the total area %.

A = total area of zone m^2.

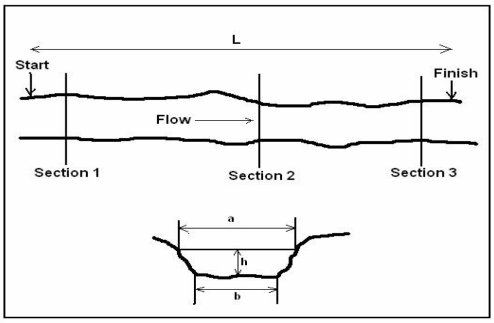


Fig .4. The cross section in traditional canal (Mesqa)

Fig. 5. Shows the width in traditional canal (Mesqa)

7- Conveyance efficiency

The conveyance efficiency was measured in earthen canal by measuring discharges from pump by using a tank of known size in known time and measuring the discharge at the entrance of the fields by using pipe and tank of. The conveyance efficiency was obtanied by the equation (3) according to Howell (2003). This test was replicated five times in summer and five times in winter.

$$E_c = \frac{W_f}{W_d} \times 100 \quad \ldots\ldots\ldots\ldots (3)$$

Where

E_c = conveyance efficiency %.

W_f = Water delivered to the irrigation plot m3

W_d = Water diverted from the source m3.

8- Application efficiency (Ea).

Water application efficiency was calculated from the following formula (4) according to **(FAO, 1989):-**

$$Ea = [W_{DZ} / D_T] * 100 \quad \ldots\ldots\ldots\ldots (4)$$

Where:

W_{DZ} = Depth of water stored in the root zone cm,

D_T = Gross depth of applied water cm.

Soil moisture distribution "SMD" was determined according to Liven and Van Rooyen (1979). For each treatment, six locations were taken along the field. The soil moisture content was determined using the gravimetric method. SMD was identified at six points along field and three depths at root zone (0--20, 20-40 and 40-60) before and after irrigation. Soil samples were collected by soil auger. Moisture content for each treatment was measured directly before irrigation and 48 hours after irrigation. Soil moisture content percentage (S.M.C.) % was determined as a dry weight according to the following equation (5):

$$S.M.C = (W_1 - W_2) / W_2 * 100 \quad \ldots\ldots\ldots\ldots (5)$$

Where:
W_1 = weight of the wet soil sample (g)
W_2 = weight of the oven dried soil sample (g) at 105 ^{0}C for24 hours.

Equation (6) was used to find the depth of water that entered to root zone ($W_{DZ)\,mm}$ during irrigation.

$$\mathbf{WDZ = (S.M.C2 - S.M.C1)\rho * D * 100} \quad . (6):$$

Where:
ρ: specific weight of soil
S.M.C2; soil moisture content in the Field 48 hours after irrigation
S.M.C1 ; is moisture content in the field before irrigation.
D: root depth (cm)

9-field Water use efficiency (FWUE)

After determining the amount of water applied to crop in the season. Water use efficiency was calculated according to the following equation (7) according to(Howell, 2003).

$$FWUE\,(kg/m^3) = \frac{Yield,(kg/\,fed.)}{Water\ applied,(m^3/\,fed.)} \times 100 \quad ------- \quad (7)$$

RESULTS AND DISCUSSION

1-Effect of buried pipes and lining canal as improved conveyance systems on decreasing land losses in irrigated fields.

Mesqa and Marwa are the last water conveyors in the old land irrigation system in Egypt. Where irrigation water lifted from branch canals to mesq's and flow through mesq's to maraw's and to the field. Traditional mesq's and maraw's network occupying space of agricultural land therefore, using buried pipes network instead of Traditional mesq's and maraw's increased planted area. The results shown in Fig. (7) Indicated that the area added to 96 feddan was 2.0914 feddan which represent ratio of 2.74 %. In the 49 feddan field an area of 1.023 feddan was added which represent ratio of 2.087% while in the 30 feddan of area there was 0.6202 feddan added with percentage of increase 2.067%. The average percentage of increase in the all fields was 2.3%.

Using lining canal instead of Traditional mesq's and maraw's resulted in increasing of planted area and the results are shown in table (2) where the area added to 96 feddan was 1.27feddan with 1.33 % percentage of increase and in area of 49 feddan the area added was o.509 feddan with 1.047% percentage of increase. In area of 30 feddan the area added was 0.383 feddan with 1.04% percentage of increase. The average percentage of increase in the field area was 1.2%. Water conveyance losses consist mainly of operation losses, evaporation and seepage into the soil from the side surfaces and bed of the canal. The conveyance efficiency (Ec) mainly depends on the length of the canals, the soil type or permeability of the canal banks and the condition of the canals. Data in Table (3) shows the conveyance efficiency (Ec) of 432 m earthen Mesqa was 81.37 % in summer season while, in winter season it was 83.46%. The conveyance efficiency (Ec) was 91.83 % in summer season for 412m lining Mesqa and 93.59% in winter season. The conveyance efficiency (Ec) of the buried pipes in summer season was 98.37 % for 527 m length of buried pipe and in winter season it was 98.41%. The conveyance losses in earthen Mesqa ranged from 18.63% to 16.54% due to evaporation and seepage into the soil. In lining canal there isn't seepage so, the conveyance losses is less than earthen Mesqa it was 8.17 % to 6.41 %. The conveyance losses in buried pipes were 1.59% 1.63% which may be due to small leakage.

Table 2. Effect of buried pipes and lining canal as improved an irrigation conveyance systems on the land losses in the irrigated area:

Area (feddan)	Type	Add area (feddan)	The percentage add area
96	Buried pipes	2.0914	2.74 %
49	Buried pipes	1,023	2.087 %
30	Buried pipes	.6202	2.067 %
96	Lining canal	1.27	1.33 %
49	Lining canal	.509	1.04 %
30	Lining canal	.383	1.27 %

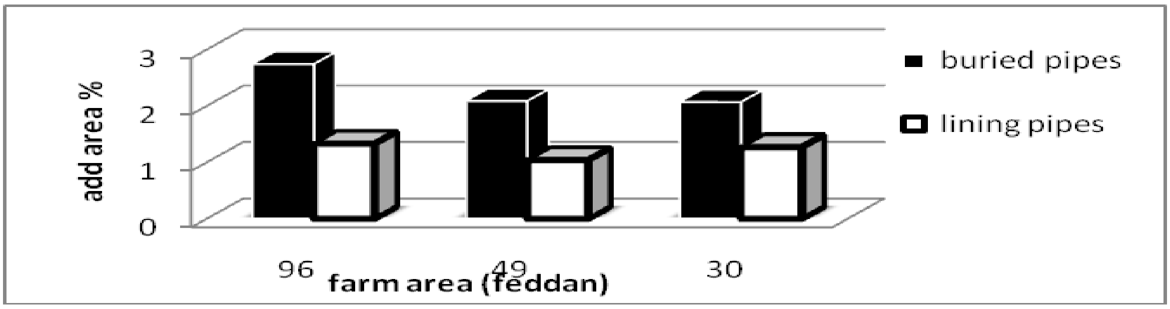


Fig. 7. percentage of area added due to using buried pipes and lining canal instead of traditional canal .

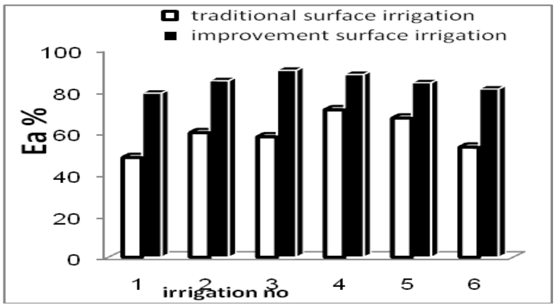
2- Effect of using buried pipes, lining Mesqa and lining Marwa instead of earthen Mesqa and Marwa on conveyance efficiency.

Table (3) Conveyance efficiency (Ec) in earthen canal (Mesqa), lining canal and buried pipes

Canal type	Length m	Season	In flow m^3/ h	Out flow m^3 /h	Conveyance efficiency%
Earthen canal (Mesqa)	432	Summer	253.8	206.51	81.37
Earthen canal (Mesqa)	432	Winter	253.4	211.48	83.46
Lining canal	412	Summer	206.38	189.51	91.83
Lining canal	412	Winter	206.38	193.15	93.59
Buried pipes	527	Summer	174.56	171.71	98.37
Buried pipes	527	Winter	174.56	171.78	98.41

3- Application efficiency (Ea)

Water application efficiency was calculated for the different irrigations and the values are shown in Fig: (8a) and (8b). Irrigation application efficiencies were 79, 85, 80, 84, 78 and 81% with average 81% during the first season under improved surface irrigation. In second season the application efficiencies were 80, 81, 83, 87, 79, and 84% with average 82%. Under traditional surface irrigation while traditional land leveling the application efficiencies were 48, 60, 58,71,67 and 53 % with an average of 59,5% during the first season. In second season the application efficiencies were 49, 62, 59, 45,69and 67% with an average of 58.5%. The results show that irrigation application efficiency under improved surface irrigation was higher by 21.5% during first season and by 23.5% during second season as compared with traditional surface irrigation so, it could be concluded that, improved surface irrigation saved a considerable volume of water.



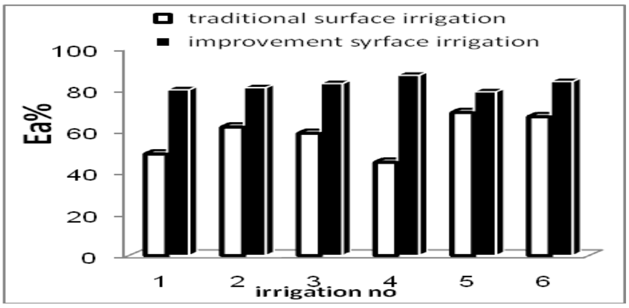
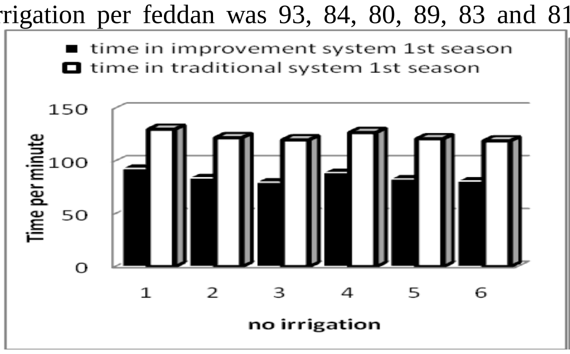


Fig (8a) and (8b). Application efficiency during1st season and 2nd season.

4- Irrigation time

One of the benefits of surface irrigation improvement which converting traditional Mesqa and Marwa to buried pipe is to facilitates irrigation operation and reduces the necessary time to irrigate an area of one feddan. Fig (9) shows the results of the irrigation time in two consecutive seasons under improved and traditional surface irrigation. In first season under improved surface irrigation the time of irrigation per feddan was 93, 84, 80, 89, 83 and 81 minute with average 85 minute while traditional surface irrigation the time of irrigation per feddan was 130, 122, 120, 127, 121 and 119 minute with an average of 123 minute. In the second season under improved surface irrigation the time of irrigation per feddan was 90, 80, 79,82, 81 and 80 minute with average 82 minute while under traditional surface irrigation the time of irrigation per feddan was 125, 120, 118, 116, 114,and 112 minute with average 117.5 minute.



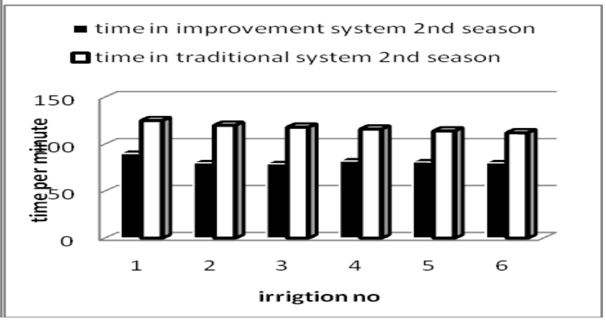


Fig 9. Effect of improved and traditional surface irrigation on irrigation time saving in 1st season and 2^{nd} season.

5- Productivity of crop.

The grain yields obtained from the improved and traditional surface irrigation are illustrated in table (4). The quantity of wheat and sorghum yield was affected by using improved surface irrigation where, it is high compared with traditional surface irrigation. The quantity of sorghum was 2345 kg/ fed and 2100 kg/ fed under improved and traditional surface irrigation respectively. In wheat the productivity was 2775 kg/ fed and 2475 kg/ fed under improved and traditional surface irrigation respectively. The lowest value of wheat and sorghum was under traditional surface irrigation. The percentage of increase in the productivity of wheat and sorghum under improved surface irrigation was 10.81% and 10.44 % respectively.

Table (4). Effect of improved surface irrigation on productivity of crop

Crop	Type of surface irrigation	Productivity kg/ fed	increase Percentage %
Wheat	Improved surface irrigation	2775	
Wheat	traditional surface irrigation	2475	12.12
Sorghum	Improved surface irrigation	2345	
Sorghum	traditional surface irrigation	2100	11.66

6- Effect of improved surface irrigation on field water use efficiency.

Concerning field water use efficiency (FWUE), as an evaluation parameter describes of crop response to irrigation water applied. The (FWUE) is expressing the productivity of irrigation water. Field water use efficiency (FWUE) which is defined on the crop production per each unit of water applied. Where (FWUE) determined for wheat and sorghum under improved and traditional surface irrigation system. Table (5) illustrates the effect of improved surface irrigation systems on wheat and sorghum field water use efficiency compared with traditional system. It was found that the values of (FWUE) under both improved and traditional surface irrigation were 1.49 kg/m^3 0.87 kg /m^3 and for wheat respectively. The value of (FWUE) for sorghum under both improved and traditional surface irrigation systems were 1.08 kg/m^3 and 0.631 kg/m^3 respectively. According to the above mentioned results in tables (4) and (5) it could be could be concluded that under improved surface irrigation, crop yield was high and irrigation water applied was less than that under traditional surface irrigation .consequently (FWUE) become higher under improved surface irrigation system than that under traditional irrigation system for both crops wheat and sorghum .

Table (5) Effect of improved surface irrigation on (FWUE) for wheat and sorghum crops

Type of irrigation	Type of crop	Yield kg/fed	Water applied m^3/fed	WUE kg/m^3
Improved surface irrigation	Wheat	2775	1861.9	1.49
Traditional surface irrigation	Wheat	2475	2822.4	.87
Improved surface irrigation	Sorghum	2345	2155.3	1.08
Traditional surface irrigation	Sorghum	2100	3323.6	.631

CONCLUSIONS

Field experimental works were conducted along two successive summer seasons of 2015 and 2016 in Upper Egypt at Sohag governorate – Monsha city at Nasser branch canal in (OFIDO) national project. The study was conducted to evaluate the improved surface irrigation system and their effects on field water use efficiency and yield as the base for integrated surface irrigation management in the old lands.

Where application of (OFIDO) national project leads to the following:

- Equitable distribution of irrigation water for all farms on (Mesqa).
- Uses the buried pipes instead of Traditional mesq's and maraw's led to increased agricultural area with a rate of 2.3% and with a rate of 1.2% in lining canal.
- Raise The conveyance efficiency from 81.37 % in earthen Mesqa to 91.83 % in lining Mesqa and 98.37 % in buried pipes.
- Raise The application efficiency from 58.5% in traditional surface irrigation to 82% in improved surface irrigation .
- Decreasing irrigation time from 123 minute per feddan in traditional surface irrigation to 85 minute per feddan in improved surface irrigation .
- Increasing productivity of wheat and sorghum under improved surface irrigation with percentage 10.81% and 10.44 %Respectively and Thereby, increasing farmers' income.
- Increasing water use efficiency(WUE) from.87 kg.m-3 to 1.49 kg.m-3 for wheat under improved surface irrigation and from.631 kg.m-3 to 1.08 kg.m-3 for sorghum under improved surface irrigation.

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تقييم الادارة المتكاملة للري السطحي في الاراضي القديمة

محمد رجب[1] ، محمد الانصاري[1]، منتصر عواد[1] و احمد صلاح[2]

1- قسم الهندسة الزراعية كلية الزراعة جامعة بنها

2- **معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية**

اجريت هذه الدراسة بمنطقة الكوامل مركز المنشاة بمحافظة سوهاج بصعيد مصر. بهدف تقييم تطبيقات مشروع تطوير الري الحقلي بالاراضي، القديمة تحت ظروف الادارة المتكاملة للري السطحي، التي تهدف الي رفع كفاءة استخدام المياه ومعظمة الانتاجية وتحديد مدي قدرة هذا المشروع القومي علي تقليل فواقد المياه ورفع كفاءة نظام الري السطحي .ولقد تم التقييم من خلال حساب وقياس المؤشرات الآتية: نسبة الزيادة في مساحة الارض الزراعية ، وكفاءة نقل المياة ، وكفاءة الاضافة ، وزمن ري الفدان ، زيادة انتاجية الفدان ، كفاءة استخدام المياة الحقلية.حيث كانت النتائج علي النحو الآتي :نسبة المساحة الزراعية التي سيتم اضافتها للاراضي الزراعية التي يتم فيها تطوير الري لحقلي هي 2.74% الي 2.06% نتيجة استبدال المساقي والمراوي الترابية بمواسير مدفونة ، وبنسبة تتراوح بين 1.33% الي 1.04% نتيجة استبدال المساقي والمراوي الترابية باخري مبطنة.زيادة كفاءة النقل من 82.4% في المساقي الترابية الي 92.7% في المساقي المبطنة الي 98.38% في المواسير المدفونة.زيادة كفاءة الاضافة من 59% في الري التقليدي الي 81.5% في الري السطحي المحسن. تقليل زمن الري للفدان الواحد في الري السطحي المحسن بنسبة 31.39% مقارنة بالري السطحي التقليدي.نسبة الزيادة في انتاجية الفدان الواحد تحت نظام الري السطحي المحسن 10.81% للقمح ،و 10.44% للذرة الرفيعة مقارنة بالري السطحي التقليدي.زيادة قيمة كفاءة استخدام المياة لمحصول القمح من .87kg/m^3 تحت نظام الري السطحي التقليدي الي 1.49kg/m^3 تحت نظام الري السطحي المحسن،ولمحصول الذرة الرفيعة من.31 kg/m^3 الي 1.08 kg/m^3.