International Scholars Journals

International Journal of Irrigation and Water Management ISSN: 2756-3804 Vol. 8 (2), pp. 001-010, October, 2021. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Interlinked ArcGIS and AutoCad Application in improving Irrigation Scheme Precision in Case of Wonji Shoa

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Accepted 03 October, 2021

Abstract

This paper was initiated with specific aim of increasing the precision of irrigation scheme specifically infield irrigation management. In achieving such objective profound software like AutoCAD, ArcGIS and CROPWAT were used with respective their input data. Through interlinking the output of AutoCAD that is field layout map which give no information about the Soil Class of the field, and ArcGIS output that is soil management group which lacks the specificity of the field, the enhancement of infield irrigation precision was achieved as the information contained in both maps were mingled/associated to gather. Finally old Soil cycle map was substituted with to field level detailed Soil management group and irrigation interval, depth, and cutoff time were determined and recommended to Wonji Sugar Estate.

Keywords: Soil Management Groups, Soil Cycle, Infield Irrigation

INTRODUCTION

Wonji-Shoa Sugar Factory WSSF is one of the old state commercial farms established during 1950s not only to produce white sugar, but also advertise its importance for local consumption. The Areal coverage of the commercial farm is now about 14000ha both from state and out growers. WSSF depend on Awash River for its water needs; irrigation, industrial need and service. Water from Awash River is diverted, stored and/or supplied to the farm to satisfy water requirement for evapotranspiration of Sugarcane that is produced to enhance white Sugar production by pump. Sugarcane is a tropical, perennial grass that forms lateral shoots at the base to produce multiple stems, typically three to four meters high and about five cm in diameter. The stems grow into cane stalk, which when mature constitutes approximately 75% of the entire plant. A mature stalk is typically composed of 11–16% fiber, 12–16% soluble sugars, 2–3% non-sugars, and 63–73% water. A sugarcane crop is sensitive to irrigation, soil type, fertilizers, insects, disease control, varieties, and the harvest period [1].

Literature implies that cane productivities is strongly dependent on irrigation water. Since ancient days water is essential component of human life and the mannerism of water use or culture in a society is indication of level of civilization. And also water is political commodity; in contrary to this fact, fresh water is depleting from time to time in worldwide because misuse of water. In Ethiopia, Agriculture is the core driver for economy, base for food security and food self-sufficiency. Agriculture directly supports 85 percent of the population's livelihoods, 41.6 percent of gross domestic product (GDP) and over 80 percent of export value [2]. But rainfed Agriculture is not dependable and therefore should be transformed to irrigated farm like sugar cane commercial farm and small scale irrigation scheme. Ethiopia government planned and embarked huge projects to expand sugar cane commercial farm GTP. But in the existing cane commercial farm, there is poor infield irrigation management and monitoring policy that matter very much. As a manifestation such implication, recent study indicated that Sugarcane plantation of Wonji-Shoa Sugar Factory was significantly reduced in productivity [3].

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Within 50 years of production, yield was decreased at least from 200,000 to 120,000 ton or 40% mainly because of ground water table rise/water logging mainly & other cumulative effect. In field irrigation is very poor the irrigation depth is not known and then irrigation interval too (observation and formal interview).

Appropriate irrigation management needs strong logistics to diagnostic limitation, introduce enact systematic irrigation operation management. Technologies like GIS in the field of Irrigation is compulsory to systematic irrigation operation management to optimize the return through water saving and increasing productivity [4].

Specific objectives:

To determine irrigation depth and frequencies with respect to soil, crop and metrological data of the study area over cropping seasons for sugarcane

To produce interlinked map of Wonji-shoa irrigation Scheme using Auto-cad aid field layout and GIS aid soil management group map

To evaluate existing irrigation practices comparing with improved water management approach [5].

Materials and Methods

Description of the study area

Wonji-shoa Sugar Estate is located at 8031' N and 39012' E with an altitude of 1500 m.a.s.l. The area has annual rainfall of 814mm, with Max/Min air temperature of 27.9/12.9C0 and mid-day relative humidity is of 47%. In general, it has a sub-humid climate having bimodal rainy seasons, the main rainy season from July to September. Therefore, irrigation is practiced in the rest of the months to grow sugarcane. Soils of the Sugar Estate are classified as fine textured soils (A1, A2, and BA2 soil management groups) and coarse textured soils (B1.4 and C1 soil management groups).

Methods of the study

Materials

In the implementation of this research work, software like ArcGIS version 10 from ESRI, AutoCAD version 16 were used for map production from available map such field layout map, Soil management group map and soil class map while CROPWAT 8 was used for in processing metrology data and producing irrigation scheduling. GPS aided point data were also geo-referenced point data used in integration in Arc-GIS to produce guided map specially during linking attribute (samples from field) with digitized layout, Soil management group and soil class map, index table 1, 2, 3.

Primary and Secondary data

Primary data collected during implementation of this research were soil data those determinant such as field capacity (FC; pF 2.5), permanent wilting (PWP; pF4.2), soil texture (sand, silt and clay), bulk density, bd, particle density ,pd, Electrical conductivity, EC (1:5), Soil pH (1:5), were sampled and analyzed in Wonji Soil Lab, Index **(**Table 4**)**.

Secondary data such soil infiltration rate, metrological data such precipitation, mm, air temperature (Max/Min C0), air pressure (relative humidity %), Sun shine hour, hr and wind speed, km/d were collected from BRL, 2013 and Wonji Metrological Station respectively and processed for appropriate use, table 1-5.

Some data such crop data; sugarcane growth stages initial stage and yield response factor, (0-90days, 0.58); development stage, (90days - 180days, 0.93); mid stage (180 days - 450day, 1.18); and late stage (>450 days, 0.98) and critical point, 40% and yield response factor 0were collected from FAO, 1998.

Table 1: Sugarcane data

Sugarcane stage	Interpolated KC	Interpolated
0 -3 month	0.58	0.4-0.75
3 - 6 month	0.93	0.75-1.1
6 - 15 months	1.18	1.1-1.25
> 15 months	0.98	1.25-0.7

Crop water requirement

Crop water requirement is the amount of water required to compensate the evapotranspiration loss from cropped field which was determined by using empirical method. In the empirical method reference evapo-transpiration (ETo), and factors known as crop coefficients (Kc) were used which vary from crop to crop and depending on the stage of the crop (Table 1). The daily reference evapo-transpiration (ETo) and effective rain fall in respective months were determined with computer program (CROPWAT model) based on the Penman-Monteith equation (Allen et al., 1998). Therefore, sugar cane crop evapo-transpiration (ETc) was calculated as:

$$ETc = Kc * ETo \qquad [1]$$

Application depths

Proper irrigation depth can be determined from known plant and soil characteristics. The maximum required depth can be determined from the total available soil moisture (TAM) between field capacity and wilting point and the allowable depletion fraction. Together with effective crop rooting depth, this gives the maximum depth to which the soil can dry out and the depth the irrigation water supply must reach by the end of an irrigation interval. Then depth of application was determined using the following formula:

$$Dn = TAM * P * Dr \quad [2]$$

Where,
TAM = total available soil moisture (mm/m),
P = allowable depletion (fraction),
Dr = effective root depth (m),
Dn = Net depth of application (mm)

Net irrigation requirement (NIR) is obtained by subtracting from crop water requirement (ETc) the expected incoming of moisture in the soil water balance. The gains include effective rainfall (Reff), capillary rise from ground water and stored soil moisture. Here, however, the Net irrigation water requirement basically represents the difference between crop water requirement and effective rainfall. Hence, net irrigation water requirement is determined as:

$$NIR = Etc - \mathrm{Re}\,ff \quad [3]$$

Where,
NIR = , net irrigation water requirement (mm)
ETc = peak crop water requirement (mm/day)
Reff = effective rainfall (mm)sandstone aquifer which underlains the whole Western

Irrigation Interval

Proper irrigation frequency or interval (I) in days was estimated relating the net application depth to the daily crop water requirement as the following formula:

$$\mathrm{I} = \frac{\mathrm{D_n}}{\mathrm{ETc}} \quad [4]$$

Where: I = irrigation interval (days)
Dn = Net depth of application (mm)
ETc = peak crop water requirement (mm/day)

Cut off time

Cut-off time is the time at which the supply is turned off, measured from the onset of irrigation. it is another important field irrigation management practice. There should be well defined inflow time that irrigators use in the field. Furrow length, furrow spacing, and water inflow rates WWDSE (2008), were carefully utilized to determine time of irrigation water application (Tco) or cut-off time to the cane field furrows. To supply the required amount of water to the full furrows with a given flow rate, cutoff time was determined using the following equation.

$$\mathrm{T_{co}} = \frac{\mathrm{LxWxD_n}}{\mathrm{60xQxEa}} \quad [5]$$

Where:
Tco = time of cutoff (min),
L = furrow length (m),
W = furrow spacing (m),
Dn = net depth of application (mm),
Qo = flow rate (l/s),
Ea = application efficiency (fraction)

Digital Soil Map Production

As resource there were three maps produced; field layout, Soil class, and soil management groups lacking integration or link. In the first place these maps in form of pdf format; which is vector data or raster data and therefore cannot be processed further. Therefore digitized from existing soil maps is the only option otherwise lead to high investigate human capital. Geo-referenced data will be interlinked with attribute data. Mapped used as monitoring tool for irrigation crew.

Captured data will be converted into appropriate unit. Then appropriate database was established in GIS software. After appropriate data is created, the geo-referenced data will be imported to GIS where shape file will be created. Shape file created on GIS will be then displayed in Global mapper. And there digital elevation model and/or topography map will be displayed along with the created shape file. For further edition, displayed data will be saved in respective created database. The source of meteorological data for this project will be Wonji and other nearby meteorological stations will be used. And those data, all necessary (altitude, location, mean annual precipitation, min/max/mean temperature) crop evapotranspiration.

Results and Discussions

In the diagnostically testing Wonji Sugar Estate data produced in by BRL Engineering Consulting Institution, were used to come up with soil digital map instead of the old soil cycle map. In doing that the data gathered from BRL documents were tested for reliability.

3.1 Soil Data Analysis

Soil Water holding Capacity

The guiding line in surveying the soil unit map produced by BRL which are Vertisoils (VP, VPb, V, Vb), Clays (C, Cb), Loamy, sandy, stratified soils (Cx2, Cx5) that are characterized with some of the soil character determining factors that are indexed to this paper, index table A. About 74 fields were sampled to systematically represent the all soil map units. Two samples were collected from a field at a depth of 0-30cm and 30-60cm for a single sample.

Table 2: Water holding Capacity for Soil management group of Vertisoils

Profile No.	Location		Soil type	Depth, cm	% moisture (wt.)		Blk density, g/cc	FC, %	PWP,%	AWC, % vol
P2	523995	932989	VP	Oct-15	42.7	24.4	1.7	30.9	18.25	30.91
P2			VP	43-48	42.4	24.7	1.7	30.1	17.72	30.11
P6	528393	927909	V	04-Sep	41.9	23.1	1.5	28.9	18.78	28.89
P6			V	36-41	42.6	23.8	1.6	30.1	18.79	30.15
P6			V	51-55	42.7	21.3	1.7	35.9	21.47	35.91
P9	528415	931022	VP	03-Aug	40.8	22.8	1.5	26.5	17.96	26.53
P9			VP	32-37	42.6	24.9	1.6	28.4	17.76	28.39
P9			VP	58-63	42.3	23.4	1.6	30.1	18.97	30.07
P20	526375	930494	Vb-s1	05-Oct	43.9	24.8	1.5	28.6	19.1	28.62
P20			Vb-s1	23-28	44.7	22.2	1.7	38.7	22.47	38.69
P20			Vb-s1	55-60	39.1	21.9	1.8	31.6	17.19	31.57
P29	523647	928827	V-anv	02-Jul	27	14.7	1.2	14.7	12.26	14.73
P29			V-anv	41-46	33.7	17.8	1.2	19.1	15.92	19.1
P29			V-anv	65-71	39.6	17.6	1.4	30.3	22.03	30.32
P35	529196	931998	VP	Oct-15	43.7	24.6	1.6	30	19.14	29.98
P35			VP	40-45	44.5	24.2	1.7	33.6	20.32	33.55
P35			VP	60-65	42.4	24.5	1.7	30.1	17.87	30.1
					41	22.4			18.6	**29.27**

Table 3: Water holding Capacity for Soil management group of Clays

Profile No.	Location		Soil type	Depth, cm	% moisture (wt.)		Bulk density, g/cc	FC -WP	AWC, % vol
P3	524025	931462	Cb-s1	Oct-15	39.2	24.9	1.7	14.3	24.67
P3			Cb-s1	40-45	35.1	26.3	1.7	8.8	15.29
P16	532822	927036	Cb-s2	15-20	33.9	19.9	1.5	14	20.64
P16			Cb-s2	45-50	34.3	20.3	1.3	14	18.43
P17	528056	932962	C	02-Jul	46.5	22.8	1.3	23.7	31.35
P17			C	22-27	44.9	16.8	1.6	28.2	46.33
P17			C	45-50	45.4	21.5	1.7	23.9	40.37
P27	524004	932508	C-s1	04-Sep	42.2	20.5	1.7	21.7	36.2
P27			C-s1	20-25	39	21.5	1.6	17.5	27.67
P39	526350	934030	C	06-Nov	44	19.7	1.4	24.3	34.34
P39			C	32-37	44.6	22.7	1.6	21.9	35.3
P39			C	50-55	43.8	22.4	1.7	21.4	36.22
					41.1	21.6		19.5	**30.46**

Table 4: Water holding Capacity for Soil management group of Loamy, sandy, stratified soils.

Profile No.	Location		Soil type	Depth, cm	% moisture (wt.)		Bulk density, g/cc	Porosity, %		FC -WP	**AWC, % vol.**
P10	527984	929972	Cx5	14-19	43.6	23.5	1.6	39	0	20.1	**32.6**
P10			Cx5	33-38	24.1	15.7	1.8	31	0	8.4	**15.35**
P10			Cx5	49-54	33.9	22.6	1.8	31	0	11.3	**20.5**
P28	533280	927549	Cx2	05-Oct	27.6	12.4	1.5	43	2	15.2	**22.86**
P28			Cx2	22-27	30.3	14.3	1.4	46	3	16	**22.76**
P28			Cx2	40-45	29.4	10.3	1.5	42	0	19.1	**29.2**
					31.5	16.5				15	**23.88**

Table 4: Summary of the Wonji Sugar Estate soil water holding capacity

SN	*Soil Type*	AWC, %
1	*Vertisoil*	**29.27---30**
2	*Clay*	**30.56-- 31**
3	*Loamy, sandy, stratified*	**23.88---24**

Maximum infiltration rate

Soil infiltration is one the most important parameter in irrigation scheduling. The Maximum infiltration rate, expressed in mm per day, represents the water depth that can infiltrate in the soil over a 24-hours period, as a function of soil type, slope class and rain or irrigation intensity. The maximum infiltration rate has the same value as the soil hydraulic conductivity under saturation. The Maximum infiltration rate allows an estimate of the Runoff occurring whenever rain intensity exceeds the infiltration capacity of the soil. Accordingly for Wonji Sugar Estate Soil infiltration was summarized in the following (Table 5).

Table 5: Soil infiltration

SN	*Soil Type*	Average Soil infiltration rate, mm/day
1	*Vertisoil*	101.2
2	*Clay*	151.2
3	*Loamy, sandy, stratified*	163.5

Metrological Data Analysis

For the purpose of enacting these research activities metrological data were collected from Wonji metrological station. Then the data were prepared for further inference using the CROPWAT 8. The table containing the summary of the output metrological analysis is displayed as follows were us the input has been indexed in this paper index Table 6.

Irrigation Schedule

Recently Precision Agriculture or advancement in agricultural technologies like utilization of software apps such as CROPWAT and ArcGIS Software's are significant. Likewise CropWat app was used derive application depth and interval of the sugar Estate Farm. But as a check analytical method was used to compare the result.

And the outputs (Irrigation depth which indicate how much to irrigate and irrigation interval that show when to irrigate) were displayed in the table 6. It can be noticed that irrigation interval varies constantly over the crop season and soil types.It creates peak water demands at a certain time (growth stages) while at other times water requirement will be below average.

Table 6: Reference Evapotranspiration of Wonji Sugar Estate

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	Hours	MJ/m²/day	mm/day
January	11.3	27.3	44	110	8.6	20.1	4.11
February	12	28.6	39	117	8.9	21.9	4.68
March	13	29.5	38	108	8.7	22.7	4.93
April	14.4	29.4	42	85	8.4	22.5	4.72
May	14.7	30.2	43	79	8.3	21.8	4.61
June	15.5	29.9	46	108	8	20.9	4.77
July	15.1	26.1	63	110	8.7	22.1	4.45
August	14.5	25.9	64	82	8.7	22.6	4.33
September	13.8	26.9	58	55	7.3	20.5	3.97
October	11.1	27.6	39	77	8	20.7	4.16
November	10.3	27	41	103	8.9	20.8	4.19
December	9.4	26.4	41	106	9	20.2	3.98
Average	12.9	27.9	47	95	8.5	21.4	**4.41**

Table 7: Net irrigation depth, cut off time for respective, soils, root depth and growth stages.

Growth stages	Root depth (cm)	Net irrigation depth (mm)	inflow rate l/se	Ea %	Cut off time (Min)		
	Vertisoils				Furrow length, m		
					32	48	64
0-3 months	30	17	9.4	65	3	4	5
3-6 months	45	42	9.4	65	6	10	13
6- 15 months	60	73	9.4	65	11	16	22
>15 months	90	78	9.4	65	12	17	23
Average		52		65	3	4	5
	Clay soils				Furrow length, m		
					32	48	64
0-3 months	30	18	9.4	65	3	4	5
3-6 months	45	44	9.4	65	7	10	13
6- 15 months	60	76	9.4	65	17	17	22

>15 months	90	82	9.4	65	18	18	24
Average		55		65	3	4	5
	Loamy, sandy, stratified soils				Furrow length, m		
					32	48	64
0-3 months	30	32	9.4	65	2	3	4
3-6 months	45	48	9.4	65	5	8	10
6- 15 months	60	64	9.4	65	9	13	17
>15 months	90	96	9.4	65	9	14	19
Average		60	Cons	65			

Depth of irrigation application

Infield irrigation is applied by furrows Length of furrows varies between 32m, 48m and 64m. On heavy clay soils we may expect lengths of 200m and more and slopes of maximum 60cm/km. A crew of 3 irrigators irrigates 1.2 ha/day with a flow of 75 l/s planning (scheduling) is done by the crew based on the Soil Cycle Class Map and « hand feel method » which may result in over irrigation. With the small slopes and lengths the infield irrigation in Wonji appears more to be a micro basin irrigation, which consists of filling up each furrow (BRL, 2012).

And also Yusuf evaluated the inflow rate and rated in a range 11.8 to 47 l/s not 75/s. So in this paper design flow rate (75 l/s) and Soil Cycle Map were not used but replaced by recent finding. Respectively three soil textural class (Vertisoils, Clay and loamy complex) and flow rate of 47 l/s were used. The result on net depth of irrigation application for Vertisoils, Clay and Loamy, sandy, stratified soils, with respect to Sugarcane growth stages and its average values were presented in Table 7.

Soil moisture and irrigation scheduling

Soil Available Water Capacity (AWC) is the volume of water held between field capacity (FC; pF 2.5) and permanent wilting point (PWP; pF4.2) for a specified soil depth, usually the main root zone which for most crops is 0.6 m. We recommend that to avoid over-watering, crop water requirements should adopt 0.6 m soil depth rather than the conventional 1.0 m.

Average AWC data are shown below. For the root zone, the clays and the Vertisoils each have a very high AWC, about 30% volume, equivalent to about 0.186 m3 of water for the top 0.6 m of soil. This equates to 1,900 m3/ha of water to be applied per irrigation if the soils have dried out (to PWP) or proportionally less if the AWC reserve has not been fully depleted.

Normally a crop is irrigated before PWP is reached. Of the total AWC a proportion is classed as Readily Available Moisture (RAM) which a crop can easily extract. Thereafter, remaining moisture is held at higher tensions and is progressively more difficult for plants to extract. Irrigation is commonly applied when the entire RAM has been used. Given the inherent variability and imprecision in estimating RAM, field observation of both crop and soil condition is a far more reliable way to schedule irrigation.
The loamy, sandy, stratified soil types are characterised by significant textural horizonation, so because AWC is closely related to soil texture the AWC of these soils will be very variable. We have presented average figures. The 15% volume RAM to be filled by irrigation equates to about 840 m3/ha to wet the upper 0.6 m of soil.

The estate Soil Cycle Class irrigation norms indicate an irrigation of about 2,000 m3/ha for the Vertisoils and clay soils and about 1,800 m3/ha for the lighter soils For the Vertisoils these irrigation amounts are higher than we would expect and for the other soils about double what our AWC data suggest, namely about 1,000 for the clays and 840 m3/ha for the loamy, sandy and stratified soils. Even allowing for possible differences of irrigation interval (days), we conclude that the AWC data suggest that the Cycle Class norms have resulted in over-irrigation (BRL, 2012).

Regarding irrigation interval even it is very difficult to compare with irrigation interval produced based digital soil map. But it is possible to consider max/min of the irrigation interval which is 24/17 according to data collected from Wonji Agricultural Operation

Irrigation interval

Table 7: Irrigation intervals for respective months, soils and cane growth stages.

Growth stage	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Av. interval Days
	Vertisoils soils												
0-3 months	10	8	19	12	17	15	-	-	-	12	9	7	**10**
3-6 months	13	11	16	14	16	15	-	-	-	15	13	11	**13**
6- 15 months	17	14	19	17	19	18	-	-	-	19	17	16	**17**
>15 months	23	19	27	24	28	26	-	-	-	25	23	20	**23**
	Clay soils												
0-3 months	10	8	20	13	18	16	-	-	-	12	10	8	**10**
3-6 months	14	11	17	15	16	16	-	-	-	15	13	12	**14**
6- 15 months	18	14	20	17	20	18	-	-	-	19	17	16	**18**
>15 months	24	20	29	24	28	27	-	-	-	27	24	21	**24**
Loamy, sandy, stratified Soils													
0-3 months	8	6	19	12	17	12	-	-	-	10	8	6	**8**
3-6 months	11	9	16	11	13	12	-	-	-	12	10	9	**11**
6- 15 months	14	12	15	14	16	15	-	-	-	15	14	13	**14**
>15 months	19	15	27	24	22	21	-	-	-	25	18	16	**19**

Table 8. Wonji Sugar Estate old Irrigation Interval

Sections	ET100%, Irrigation Interval in days
North west	18
Middle	20
South West	21
South	24
South East	21
North East	17

CONCLUSION

From comparing and Soil Map and Soil Cycle Class Comparison Map show that there is agreement (overlap) on only 46% of the plantation, mainly in the south of the plantation.

In other sections major discrepancies were noticed. Most seriously, an area of 2,788 ha is shown by the Cycle Class map to be light soils whereas the soil survey shows the land to be heavy clay soils and Vertisoils. Therefore it been over irrigated according to the Cycle Class norms and the soil cycle map should be replaced Soil Map.

Irrigation interval varies with soil types and irrigation months. Therefore, based on finding in this study, it is recommended that the following average irrigation intervals and cut off time should replace the old one. Field layout identification figure [1] should be used and in fact any field specific activity should be sticking to the newly derived irrigation intervals and field displayed on the digital map unless the water logging will continue and sugarcane yield decreasing will continue too.

Actual crop water requirements of sugarcane may be higher or lower than the calculated irrigation intervals. Therefore it is advisable to start soil moisture monitoring before three days of the theoretical irrigation interval.

REFERENCES

1. Fasina AS, GO Awe. And JO Aruleba.2008. Irrigation suitability evaluation and crop yield an example with Amaranthuscruentus in Southwestern Nigeria. Afr J Plant Sci. (7):61-66.
2. Roger D H, Lamm F R, Mahbub A, Trooien T P, Clark G A Barnes P L and Kyle M, 1997. Efficiencies and Water Losses of Irrigation System. Irrigation Management Series. Kansas.
3. FAO U. (1999). The future of our Land–Facing the Challenge, Guidelines for Integrated Planning for Sustainable Management of Land Resources. Food and Agri Org, Rome, Italy.
4. Oweis T. (1997). Supplemental irrigation: A highly efficient water-use practice. ICARDA.
5. Hillel D. (1997). Small-scale irrigation for arid zones: Principles and options (No. 2). Food & Agriculture Org.