

**DEVELOPMENT AND EVALUATION OF A DRIP IRRIGATION SYSTEM IN  
SOUTHEASTERN NIGERIA**

**Abstract**

Extreme climatic factors (temperature, precipitation etc) which at times lead to drought and flooding affect crop yield negatively. In this study, a PVC drip irrigation was developed and the irrigation parameters were evaluated in a farmland with three tillage methods (conventional tillage, conservative tillage and no tillage). The irrigation treatments comprised of three levels of irrigation (50% Management allowable depletion, 30% management allowable depletion and 10% management allowable depletion). Different irrigation parameters were evaluated for different crop growth stages, different soil treatments and different soil depths (0-25cm, 25-50, 50-75 and 75-100cm depths).

The field capacity was determined at -0.01MPa, from the result, the field capacity was minimum at no tillage ( $0.07\text{cm}^3/\text{cm}^3$ ,  $0.11\text{cm}^3/\text{cm}^3$ ,  $0.12\text{cm}^3/\text{cm}^3$ , and  $0.14\text{cm}^3/\text{cm}^3$ ) for soil depths 0-25cm, 25-50cm, 50-75cm and 75-100cm respectively, for conservative tillage ( $0.11\text{cm}^3/\text{cm}^3$ ,  $0.11\text{cm}^3/\text{cm}^3$ ,  $0.11\text{cm}^3/\text{cm}^3$ ,  $0.14\text{cm}^3/\text{cm}^3$ ) for 0-25cm, 25-50cm, 50-75cm and 75-100cm soil depths respectively and conventional tillage ( $0.09\text{cm}^3/\text{cm}^3$ ,  $0.13\text{cm}^3/\text{cm}^3$ ,  $0.15\text{cm}^3/\text{cm}^3$ ,  $0.17\text{cm}^3/\text{cm}^3$ ) for 0-25cm, 25-50cm, 50-75cm and 75-100cm soil depths respectively

The permanent wilting point was determined at -1.5MPa, from the result, permanent wilting point increased with increase in soil depth in conventional tillage and no tillage with PWP of  $0.01\text{cm}^3/\text{cm}^3$ ,  $0.05\text{cm}^3/\text{cm}^3$ ,  $0.09\text{cm}^3/\text{cm}^3$  and  $0.11\text{cm}^3/\text{cm}^3$  at 0-25cm, 25-50cm, 50-75cm and 75-100cm soil depths respectively for conventional tillage and PWP of  $0.02\text{cm}^3/\text{cm}^3$ ,  $0.05\text{cm}^3/\text{cm}^3$ ,  $0.05\text{cm}^3/\text{cm}^3$  and  $0.08\text{cm}^3/\text{cm}^3$  at 0-25cm, 25-20cm, 50-75cm and 75-100cm soil depths respectively for no tillage.

The average net irrigation was found to be 1.2cm, 1.56cm and 1.95cm fro conventional tillage, conservative tillage and no tillage respectively, while the average gross irrigation was found to be 1.7cm, 1.7cm and 2.1cm for conventional tillage, conservative tillage and no tillage respectively.

Statistical analysis of net and gross irrigation gave a coefficient of determination of 0.99 and p-value at 0.05 was significant with a value of 0.00007

**1.0 Introduction**

Irrigation is the application of water to the land to provide adequate moisture for crop production. Phocaides (2007) also defined irrigation as the application of water, supplementary to that supplied by precipitation for the production of crops. Man cannot depend solely on

36 rainfed Agriculture for his activities without supplementary application of water hence the need  
37 of artificial application of water cannot be underestimated in achieving a sustainable agriculture.  
38 Agriculture is the greatest user of water resources in the world totalling 70% of total withdrawals  
39 and over 80% of the consumptive use of water (Baudequine and Molle, 2003). Notably, there are  
40 large regional variations from 88% in Africa to less than 50% in Europe. In dry areas, rainfall is  
41 not enough for most crops hence irrigation makes up for the shortage. Crops suffer from  
42 moisture shortage even in areas of high seasonal rainfall for short period (USDA, 1984). These  
43 brings the importance of irrigation for great yield in crop production. Irrigation has its limitations  
44 hence there is need for calibration and irrigation scheduling for proper use of water. According to  
45 Phocaides (2007), there are two basic types of irrigation systems, namely open canal systems and  
46 pressurised piped systems. Sherer (2005) also stated that there are four basic methods of  
47 applying water, they are subsurface irrigation, surface irrigation, drip irrigation and sprinkler  
48 irrigation.

49 There is need to create technology for efficient water usage to improve water management as  
50 nature cannot be controlled. Drip irrigation system is one type of technology for improvement of  
51 water supply management and food crisis. These systems use low flow rates and low pressures at  
52 the emitters and are typically designed to only wet the root zone and maintain this zone at or near  
53 an optimum level. This conserves water by not irrigating the whole area of land. Some  
54 advantages of the drip irrigation system are smaller wetted surface area, minimal evaporation and  
55 weed growth, and potentially improved water application uniformity within the crop root zone by  
56 better control over the location and volume of water application.

## 57 **2.0 Materials and Method**

### 58 **2.1 The Study Area**

59 Field experiment was conducted at the Department of Agricultural and Bioresources Engineering  
60 Experimental Site/ Farm Workshop, Nnamdi Azikiwe University, Awka. The site lies between  
61 latitudes 6°15'11.8N to 6°15'5.3E and longitudes 7°7'118N to 7°7'183N and altitude of 142m.  
62 during the dry season, previous studies carried out in the area shows that the soil in the area is  
63 sandy loam. It is a typical of savanna covered with grass. The geologic formation of Nnamdi  
64 Azikiwe University, Awka is Imo shale (Odoh et al 2012). The Anambra River and its tributaries  
65 are the major Rivers that drain the area. There are two major climatic seasons, dry season  
66 (November to March) and rainy season (April to October) with reduced rain (August break) in  
67 August. Dry season temperature ranges from 20°C to 38°C which increases evapotranspiration,  
68 while rainy season temperature ranges from 16 to 28°C, with lower evapotranspiration. The  
69 experiment was conducted from 27<sup>th</sup> November 2017 to 22<sup>th</sup> February 2018.

70

## 71 **2.2 Materials and Equipments**

72 The materials used for the experiment were as follows:

- 73 • 25mm PVC pipe for the main line
- 74 • 12.5mm PVC for the submain
- 75 • 19mm PVC for the laterals
- 76 • 19mm end cap
- 77 • 25mm by 12.5 bend
- 78 • 12.5mm by 19mm inch bend
- 79 • 25mm ball gauge
- 80 • 12.5mm ball gauge
- 81 • 25mm by 12.5mm Tee

82 • 12.5mm by 19mm Tee

83 • 2mm drill machine

84

85 The equipments include:

86 • Pressure gauge

87 • Moisture meter

88 • Storage tank

89 • Block stand

90 • Double ring infiltrometer

91 • Measuring tape

92 • Levelling instrument

93 • Measuring cylinder

94 • Tractor

95 • Collection cans

96 • Pressure plate apparatus

97

### 98 **2.3 Field Preparation**

99 The field is a level ground and field preparation was done by dividing the plot into three major  
100 plots/sections A,B and C. Conventional tillage was done in the plot A by thoroughly tilling with  
101 plough and harrow, conservative tillage was applied in plot B by ploughing with one tractor pass.  
102 Plot C received no tillage. The tillage factor was also used in combination with three irrigation  
103 deficit levels (50% MAD, 30 MAD and 10% MAD).

104 25mm PVC pipes were used as the main line, 19mm PVC pipes served as the submain while  
105 12.5mm PVC pipes were used as the lateral. Laterals were laid at 0.5m spacing while holes were  
106 perforated in the laterals at 0.45m spacing to serve as emitter, with these, crop spacing was 0.5m  
107 X 0.45m.

108 All other necessary operations such as pest and weed controls were performed according to  
109 general local practices and recommendations

110

#### 111 **2.4 The Test Crop.**

112 The crop for the experiment was zea mays hybrid OBA SUPER 13

113 Table 2.1 Duration and Period Within the Various Growth Stages

Growth stages	Duration(days)	Period
Initial stage	14	November 27 to December 11
Crop development stage	24	December 12 to January 4
Mild stage	27	January 5 to February 1
Late stage	20	February 2 to February 22

114

#### 115 **2.5 Field Capacity Determination**

116 This was done for the three tillage methods (conventional tillage, conservative tillage and no  
117 tillage) at different soil depths (0-25cm, 25-50cm, 50-75cm and 75-100cm) using the pressure  
118 plate apparatus, it was determined at -0.01MPa matric potential.

119

120

121

## 122 2.6 Permanent Wilting Point Determination

123 This was done for the three tillage methods (conventional tillage, conservative tillage and no  
124 tillage) at different soil depths (0-25cm, 25-50cm, 50-75cm and 75-100cm) using the pressure  
125 plate apparatus, it was determined at -1.5MPa matric potential.

126

## 127 2.7 Evapotranspiration

128 This was determined daily using the Hargreaves equation (Hargreaves and Samani 1985)

$$129 \quad ET_o = a + b \cdot (0.408) \cdot 0.0023 \cdot \left( \frac{T_{max} + T_{min}}{2} + 17.8 \right) \cdot \sqrt{T_{max} - T_{min}} \cdot R_a \quad 2.1$$

130  $ET_o$  = Reference evapotranspiration

131  $T_{max}$ (°C) is the maximum daily air temperature

132  $T_{min}$ (°C) is the minimum daily air temperature

133  $R_a$  ( $MJm^{-2}d^{-1}$ ) is the extra terrestrial solar radiation converted to equivalent evaporation in mm  
134  $day^{-1}$  with a factor of 0.408.

135 The parameters  $a$ ( $mm d^{-1}$ ) and  $b$  are calibrated coefficients, determined on a monthly basis by  
136 regression analysis or visual fitting. An adjusted version of Hargreaves equation is with  $a=0$ ,  $b =$

137 1

138

139

## 140 2.8 Consumptive Use (CU)

141 Consumptive use (CU) is computed as the product of crop factor and potential  
142 evapotranspiration (Mbah, 2012). This is expressed mathematically in equation 2.2

$$143 \quad CU = KET_p \quad 2.2$$

144 Where: K = crop factor;  $ET_p$  = Potential evapotranspiration

145 The equation will be used to determine monthly consumptive use for the growing months.

## 146 **2.9 Net Irrigation Requirement**

147 The net irrigation requirement is the depth of irrigation water, exclusive of precipitation, carry-  
148 over soil moisture or groundwater contribution in soil that is required consumptively for crop  
149 production (Mbah, 2012). The maximum net depth to be applied per irrigation can be calculated  
150 using (Michael 1981) in equation 2.3:

$$151 \quad d = \sum_{i=1}^n \frac{(M_{fci} - M_{bi})}{100} \cdot A_i \cdot D_i \quad 2.3$$

152 Where:

153  $d$  = net depth of water application per irrigation for selected crop (cm)

154  $M_{fci}$  = field capacity moisture content in the  $i_{th}$  layer of the soil (%)

155  $M_{bi}$  = moisture content before irrigation in the  $i_{th}$  layer of the soil (%)

156  $A_i$  = bulk density of the soil in the  $i_{th}$  layer

157  $D_i$  = depth of the  $i_{th}$  layer of soil within the root zone (cm)

158  $n$  = number of soil layers in the root zone D.

159 **2.10 Gross Irrigation Requirement**

160 This is the net irrigation of the crop plus losses in water application and any other possible losses  
161 and will be calculated using equation 2.4.

162 
$$GIR = \frac{dn}{AE} \qquad 2.4$$

163 Where

164 GIR = Gross Irrigation Requirement(cm)

165 dn = Net Irrigation

166 AE = Application Efficiency

167 **2.11 Irrigation Frequency (IF)**

168 This refers to the number of days between irrigations during periods without rainfall. It was  
169 determined using the equation in equation 2.5.

170 
$$IF = \frac{AWC.R_z.MAD}{ET_c} \qquad 2.5$$

171 Where,

172 IF = Irrigation frequency (days)

173 AWC = Available water holding capacity(inch/ft)

174 R<sub>z</sub> = Root zone depth (ft)

175 MAD = management allowable depletion



176  $ET_c$  = crop water use rate

177 This was done for different stages of crop growth considering different depths of soil.

## 178 **2.12 Head Loss on Main Line**

179 The head loss on mainline was determined by William and Hazen Equation n equation 2.6

$$180 \Delta H = \frac{Q^{1.852}}{D^{4.872}} L \quad 2.6$$

181 Where  $\Delta H$  = energy drop by friction (m)

182  $Q$  = total discharge in the pipe (lit/sec)

## 183 **2.13 Total Energy Drop for Lateral**

184 This was determined by introducing an F-value as a reduction coefficient or determined by the  
185 integration

$$186 \Delta H = 5.35 \left( \frac{Q^{1.852}}{D^{4.872}} \right) L$$

187

## 188 **2.14 Uniformity Coefficient**

189 Uniformity coefficient (UC) was calculated using Christiansen (1942) equation in equation 2.7:

$$190 UC = 100 X \left[ 1 - \left( \frac{\frac{1}{n} \sum_{i=1}^n \{q_i - q_{ii}\}}{q_{ii}} \right) \right] \quad 2.7$$

191 Where,  $q$  = discharge

192  $q_{ii}$  = mean of discharge ( $q$ )

193 n = number of drip holes evaluated

## 194 **2.15 Statistical Analysis**

195 The statistical analysis Gross and Net Irrigation was done using the excel solver

## 196 **3.0 Results and Discussion**

### 197 **3.1 Field Capacity**

198 From the result, the field capacity was minimum at no tillage ( $0.07\text{cm}^3/\text{cm}^3$ ,  $0.11\text{cm}^3/\text{cm}^3$ ,  
199  $0.12\text{cm}^3/\text{cm}^3$ , and  $0.14\text{cm}^3/\text{cm}^3$ ) for soil depths 0-25cm, 25-50cm, 50-75cm and 75-100cm  
200 respectively, for conservative tillage ( $0.11\text{cm}^3/\text{cm}^3$ ,  $0.11\text{cm}^3/\text{cm}^3$ ,  $0.11\text{cm}^3/\text{cm}^3$ ,  $0.14\text{cm}^3/\text{cm}^3$ )  
201 for 0-25cm, 25-50cm, 50-75cm and 75-100cm soil depths respectively and conventional tillage  
202 ( $0.09\text{cm}^3/\text{cm}^3$ ,  $0.13\text{cm}^3/\text{cm}^3$ ,  $0.15\text{cm}^3/\text{cm}^3$ ,  $0.17\text{cm}^3/\text{cm}^3$ ) for 0-25cm, 25-50cm, 50-75cm and 75-  
203 100cm soil depths respectively.. At 0-25cm soil depth, there was a bigger value of field capacity  
204 in conservative tillage than conventional tillage, this could be because of runoff which occurred  
205 in the top soil in conventional tillage as there was maximum disturbance of soil. This is not in  
206 agreement with the observation reported by Alam et al., (2014). This is because the soil type is  
207 clay loam where highest FC was observed in no tillage ( $0.14\text{cm}^3/\text{cm}^3$ ), followed by conservative  
208 tillage ( $0.08\text{cm}^3/\text{cm}^3$ ). Also from the results, increase in soil depth increased field capacity which  
209 is in agreement with Alam and Salahin (2013) where field capacity increased from  $0.24\text{cm}^3/\text{cm}^3$   
210 to  $0.3\text{cm}^3/\text{cm}^3$ .

### 211 **3.2 Permanent Wilting Point (PWP)**

212 From the result, permanent wilting point increased with increase in soil depth in conventional  
213 tillage and no tillage with PWP of  $0.01\text{cm}^3/\text{cm}^3$ ,  $0.05\text{cm}^3/\text{cm}^3$ ,  $0.09\text{cm}^3/\text{cm}^3$  and  $0.11\text{cm}^3/\text{cm}^3$  at

214 0-25cm, 25-50cm, 50-75cm and 75-100cm soil depths respectively for conventional tillage and  
215 PWP of  $0.02\text{cm}^3/\text{cm}^3$ ,  $0.05\text{cm}^3/\text{cm}^3$ ,  $0.05\text{cm}^3/\text{cm}^3$  and  $0.08\text{cm}^3/\text{cm}^3$  at 0-25cm, 25-20cm, 50-75cm  
216 and 75-100cm soil depths respectively for no tillage. This is in agreement with Alam and Salahin  
217 (2013) which recorded an increase in Permanent wilting point with increase in soil depth of  
218  $0.10\text{cm}^3/\text{cm}^3$  to  $0.15\text{cm}^3/\text{cm}^3$ . For conservative tillage PWP of  $0.05\text{cm}^3/\text{cm}^3$ ,  $0.04\text{cm}^3/\text{cm}^3$ ,  
219  $0.09\text{cm}^3/\text{cm}^3$ , and  $0.07\text{cm}^3/\text{cm}^3$  were recorded for 0-25cm, 25-50cm, 50-75cm and 75-100cm soil  
220 depths respectively. There was variation in permanent wilting point for conservative tillage  
221 which could be as a result of the bulk density of the soil

### 222 **3.3 Irrigation Frequency**

223 The soil depths are the stages in soil growth as presented in Table 2.1 where, 0-25cm represents  
224 the initial stage, 25-50cm represents the crop development stage, 50-75cm represents the mild  
225 stage and 75-100cm represents the late stage.

#### 226 **3.3.1 Irrigation Frequency for Conventional Tillage**

227 At 10% MAD, irrigation frequency was 3 days, 4 days, 1 day and 4 days for 0-25cm, 25-50cm,  
228 50-75cm and 75-100 cm respectively.

229 At 30% MAD, irrigation frequency was 4days, 4days, 3days and 4days for 0-25cm, 25-50cm,  
230 50-75cm and 75-100cm soil depths respectively.

231 At 50% MAD, irrigation frequency was 4days, 10days, 6days and 5days for 0-25cm, 25-50cm,  
232 50-75cm and 75-100cm respectively.

233 Irrigation frequency is higher in 50% MAD because a lot of water was allowed to deplete from  
234 field capacity hence more days before irrigation.

235 **3.3.2 Irrigation Frequency for Conservative Tillage**

236 At 10% MAD, irrigation frequency was 3 days, 3 days, 4 day and 3 days for 0-25cm, 25-50cm,  
237 50-75cm and 75-100 cm respectively.

238 At 30% MAD, irrigation frequency was 4days, 4days, 5days and 3days for 0-25cm, 25-50cm,  
239 50-75cm and 75-100cm soil depths respectively.

240 At 50% MAD, irrigation frequency was 6days, 7days, 10days and 5days for 0-25cm, 25-50cm,  
241 50-75cm and 75-100cm respectively.

242 **3.3.3 Irrigation Frequency for No Tillage**

243 At 10% MAD, irrigation frequency was 5 days, 4 days, 4 day and 3 days for 0-25cm, 25-50cm,  
244 50-75cm and 75-100 cm respectively.

245 At 30% MAD, irrigation frequency was 5days, 5days, 5days and 4days for 0-25cm, 25-50cm,  
246 50-75cm and 75-100cm soil depths respectively

247 At 50% MAD, irrigation frequency was 5days, 6days, 4days and 4days for 0-25cm, 25-50cm,  
248 50-75cm and 75-100cm respectively.

249 Irrigation frequency is higher in 50% MAD for conventional tillage, conservative tillage and no  
250 tillage because a lot of water was allowed to deplete from field capacity hence more days before  
251 irrigation. The mean number of days is less in no tillage because runoff is more likely to occur in  
252 tilled soil than undisturbed soil.

253

254 **3.4 Evapotranspiration**

255 The Daily Evapotranspiration for the growing period was obtained from climatic data and  
256 calculated using Hargreaves equation. The maximum evapotranspiration is 7.3mm/day and this  
257 was obtained in the 38<sup>th</sup> day of the growing period. This is because the average temperature  
258 calculated from the minimum and maximum temperature is high in this periods. The least  
259 evapotranspiration is 1mm/day at 83<sup>rd</sup> day because the average temperature from the minimum  
260 and maximum temperature of the period is low.

### 261 **3.5 Consumptive Use (CU)**

262 The highest consumptive use was 6.3mm/day obtained in 38<sup>th</sup> day and minimum was  
263 0.86mm/day at 83<sup>rd</sup> day. These correspond to the days of highest and lowest evapotraspiration  
264 because consumptive use increases as evapotranspiration increases.

### 265 **3.6 Basic Hydraulics of Drip Irrigation**

266 The results of energy drop by friction for the mainline and total energy drop for the lateral are  
267 presented in

268 Basic hydraulics of the drip irrigation system

Energy Drop by Friction for mainline (m)	1.29X 10 <sup>-6</sup>
Total Energy Drop by the friction at the end of the Lateral (m)	3.6 X 10 <sup>-9</sup>

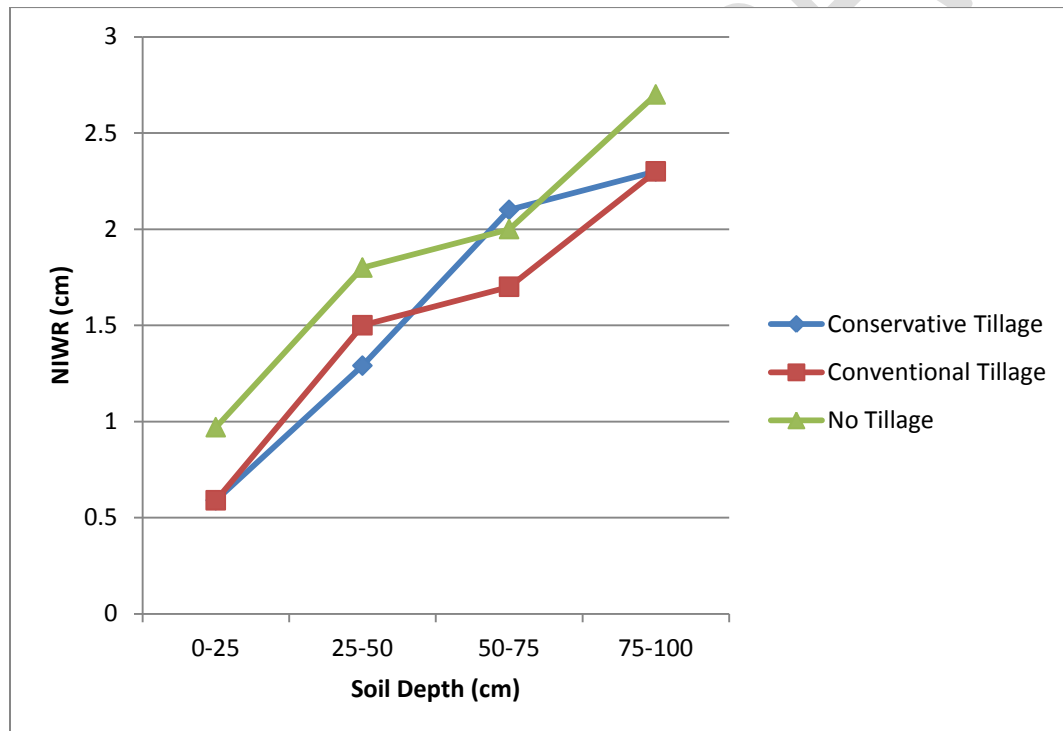
269

### 270 **3.7 Net Irrigation Water Requirement (NIWR)**

271 This is the actual amount of water necessary for cop growth, it was determined using equation  
272 For the three tillage treatments, net irrigation increased with increase in management allowable  
273 depletion, this is because more water is removed at higher management allowable depletion. The

274 average net irrigation for conservative tillage at 0-25cm, 25-50cm, 50-75cm and 75-100cm soil  
275 depth were found to be 0.59cm, 1.26cm, 2.1cm and 2.3cm respectively. For conventional tillage  
276 at 0-25cm, 25-50cm 50-75cm and 75-100cm soil depth, the average net irrigation obtained was  
277 0.59cm, 1.5cm, 1.70cm and 2.3cm respectively, while for no tillage at 0-25cm, 25-50cm,  
278 50=75cm and 75100cm soil depths an average net irrigation of 0.97cm, 1.8cm, 2.3cm and 2.7cm  
279 respectively were obtained. From the results, net irrigation increased with increase in soil depth  
280 for all the tillage methods.

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283 Fig 3.1 Effect of Soil Depth on Net Irrigation Water Requirement

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288 Table 3.1 Net Irrigation Requirement for the three tillage  
289 tillage methods at 0-25cm soil depth

Tillage method	Soil depth (cm)	MAD (%)	NIWR (cm)
Conservative	0-25	10	0.19
		30	0.6
		50	1
Conventional	0-25	10	0.19
		30	0.6
		50	1
No Tillage	0-25	10	0.317
		30	1
		50	1.6

Table 3.2 Net Irrigation Requirement for the three methods at 25-50cm soil depth

Tillage Method	Soil Depth (cm)	MAD (%)	NIWR(cm)
Conservative	25-50	10	0.43
		30	1.29
		50	2.15
Conventional	25-50	10	0.51
		30	1.5
		50	2.5
No Tillage	25-50	10	0.605
		30	1.81
		50	3.0

299 Table 3.3 Net Irrigation Requirement for the three tillage  
300 tillage methods at 50-75cm soil depth  
301

Tillage Method	Soil Depth (cm)	MAD (%)	NIWR (%)
Conservative	50-75	10	0.7
		30	2.1
		50	3.5
Conventional	50-75	10	0.234
		30	0.70
		50	1.17
No Tillage	50-75	10	0.79
		30	2.4
		50	3.0

Table 3.4 Net Irrigation Requirement for the three methods at 75-100cm soil depth

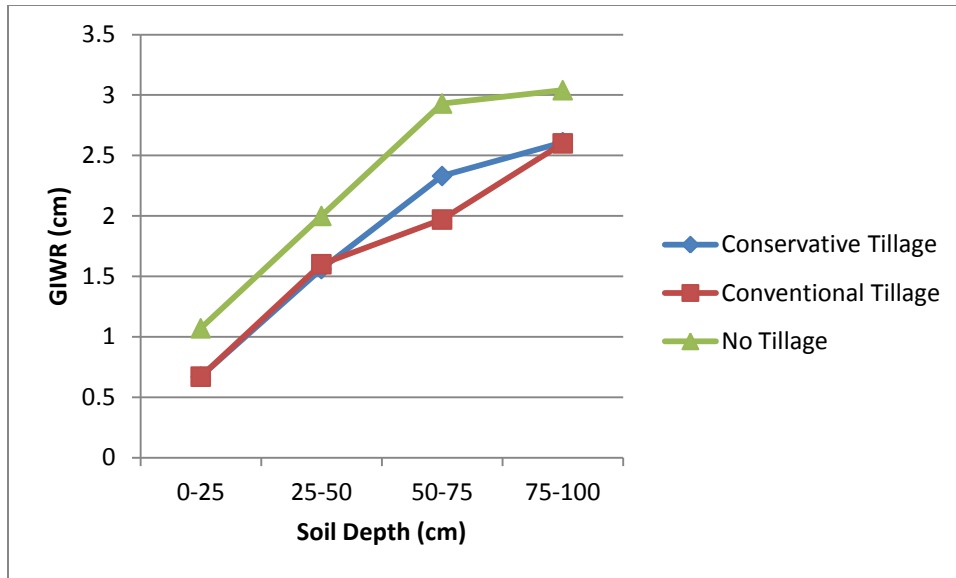
Tillage Method	Soil Depth (cm)	MAD (%)	NIWR (%)
Conservative	75-100	10	0.77
		30	2.31
		50	3.9
Conventional	75-100	10	0.77
		30	2.31
		50	3.9
No Tillage	75-100	10	0.924
		30	2.77
		50	4.6

302

### 303 3.8 Gross Irrigation Water Requirement (GIWR)

304 This is the quantity of water to be applied in realty, taking into consideration water losses

305 There was increase in gross irrigation with increase in soil depth, this is because of the net  
306 irrigation which increased with increase in soil depth. For conservative tillage at 0-25cm, 25-  
307 50cm, 50-75cm and 75-100cm soil depths, there were average gross irrigations of 0.67cm,  
308 1.56cm, 2.33cm and 2.61cm respectively. For conventional tillage at 0-25cm, 25-50cm, 50-75cm  
309 and 75-100cm soil depths, average gross irrigations recorded are 0.67cm, 1.69cm, 1.97cm and  
310 2.6cm respectively while for no tillage at 0-25cm, 25-50cm, 50-75cm and 75-100cm, gross  
311 irrigations of 1.07cm, 2.00cm, 2.64cm and 3.04cm respectively was obtained.



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313 Fig 3.2 Effect of different tillage practices on gross irrigation water requirement

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328 Table 3.5 Gross Irrigation Requirement for the three tillage  
329 tillage methods at 0-25cm soil depth

Tillage Method	Soil Depth (cm)	MAD (%)	NIWR (%)
Conservative	0-25	10	0.21
		30	0.7
		50	1.1
Conventional	0-25	10	0.21
		30	0.7
		50	1.1
No Tillage	0-25	10	0.35
		30	1.11
		50	1.77

330

331

332 Table 3.7 Gross Irrigation Requirement for the three tillage  
333 three tillage methods at 50-75cm soil depth

Tillage Method	Soil Depth (cm)	MAD (%)	NIWR (%)
Conservative	50-75	10	0.77
		30	2.33
		50	3.9
Conventional	50-75	10	0.26
		30	0.77
		50	1.9
No Tillage	50-75	10	0.87
		30	2.67
		50	4.4

334

335

### 336 3.9 Uniformity Coefficient

337 This was also calculated using equation 3.16 and shown in table 3.9 below

338 Table 3.9 Result of Uniformity Coefficient

Uniformity Coefficient @10%MAD (%)	Uniformity Coefficient @ 30%MAD (%)	Uniformity Coefficient @ 50%MAD (%)
96	99	99

339

Table 3.6 Gross Irrigation Requirement for the three methods at 25-50cm soil depth

Tillage Method	Soil Depth (cm)	MAD (%)	NIWR (%)
Conservative	25-50	10	0.5
		30	1.43
		50	2.77
Conventional	25-50	10	0.6
		30	1.7
		50	2.7
No Tillage	25-50	10	0.67
		30	2.01
		50	3.34

Table 3.8 Gross Irrigation Requirement for the tillage methods at 75-100cm soil depth

Tillage Method	Soil Depth (cm)	MAD (%)	NIWR (%)
Conservative	75-100	10	0.9
		30	2.6
		50	4.33
Conventional	75-100	10	0.9
		30	2.6
		50	4.3
No Tillage	75-100	10	1.03
		30	3
		50	5.1

340 There was uniformity coefficient of 96% for 10% MAD, 99% for 30% MAD and, 99% for 50%  
341 MAD. Uniformity coefficient up to 90% is acceptable. The uniformity coefficients in table 4.12  
342 are within the acceptable range.

### 343 3.10 Statistical Analysis

344 Table 3.10  $R^2$ , Multiple R, Standard Error and Observation Table for Bulk Density and Least  
345 Limiting Water Range

Multiple R	R Square	Standard Error	Observation
0.99	0.99	0.104	11

346

347

348 Table 3.11 ANOVA for Gross and Net Irrigation

	Df	SS	MS	F	P - Value @ 0.05
Regression	1	35.4	35.34	3248	0.00007 Significant
Residual	10	0.108	0.010		
Total	11	35.4567			

349

### 350 4.0 Conclusion

351 A PVC drip irrigation was developed and evaluated on the basis of irrigation parameters and  
352 performance evaluation. The values obtained for the parameters were in acceptable range  
353 coefficient of determination  $R^2$  value obtained for gross and net irrigation was 0.99, the p-values  
354 of  $<0.05$  shows that the terms for gross and net irrigation are significant.

355 Based on the outcome of the study, the developed drip irrigation systems performance is

356 adequate for the study area.

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