# Performance Assessment and Adoption Status of Family Drip Irrigation System in Tigray State, Northern Ethiopia

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## 1. Introduction

Large irrigation systems are generally incompatible among most of the African smallholder farming systems (De Lange, 1998) for the reason that support services for farmers, such as extension and credit are ineffective also often alter the established patterns of land tenure and land settlement, and have the effect of disrupting or undermining the established economic institutions. Moreover, improvements of surface irrigation may not be enough and due to the limited volumes of water harvested and stored as compared to crop water requirements. As a result, drip irrigation is being considered as one of the alternatives in the planning of irrigation in Tigray Regional State. Drip irrigation is often promoted as a technology that can conserve water, increase crop production, and improve crop quality. To this end, efforts to improve irrigation efficiency through new technologies have been undertaken in many areas of the Tigray Regional State. As a result, collaboration was initiated to improve irrigation efficiency between water-sector development organizations in Tigray, Ethiopia, and India, by the Norwegian Development Fund (DF) through the Triangular Project (Kirsten et al., 2008). As part of this effort, a family drip irrigation technology has been transferred from Gujarat in India to Tigray in Ethiopia, and it has spread throughout the region. There is now even a factory in Tigray that is producing the family drip irrigation (FDI) kits required for the drip irrigation.

Consequently, both governmental and non-governmental organizations have been providing technical and financial support to the family FDI beneficiaries in recent years. In this regard, selected individual household heads received one motor or pressurized treadle pump, one water tanker made of tin material having a capacity of 400 litters and a set of family drip kits to develop a 500 $m^2$ area. In addition, agricultural inputs such as vegetable seeds, fruit seedlings and fertilizer are also provided. All inputs are supplied on credit basis, which is to be paid back over a period of five years. The crops being grown were selected based on market demand.

Therefore, knowledge about performance of new irrigation technology is essential, since it serves as a base for formulation of irrigation projects. Moreover, it gives a bench mark for monitoring progresses within a given irrigation system. Thus, there is a need to evaluate the current small-scale irrigation in general and family drip irrigation in particular in the Tigray Regional State. The family drip irrigation technology is a case in point that has not been assessed in light of its technical, operational performance and adoption status. Such an assessment could assist in identifying constraints for future strategies that address water scarcity and consequently food security issues at household and national levels. Therefore, this study was undertaken to assess the performance and identify the factors that influence the technical and operational performance of family drip irrigation technology as well as its adoption status.

## 2. Materials and methods

### 2.1 Description of the study area

This study had two levels of investigation with regard to addressing the specific objectives of the study. The first was on assessment of the technical and operational performance of FDI system which was conducted in Wukro District located at 45 Km north of Mekelle, Eastern Zone of the Tigray Regional State, northern Ethiopia, while the second was on assessment of dissemination and adoption of FDI system at Tigray state's level (Fig. 1).

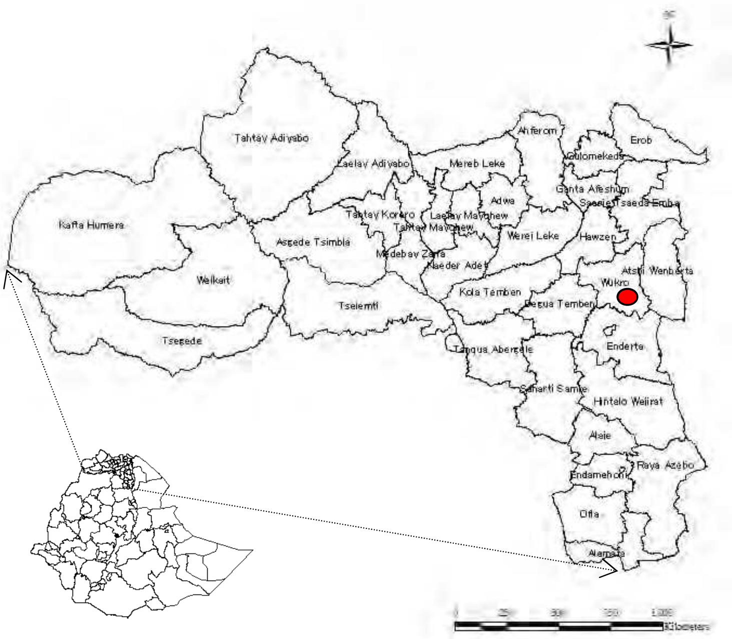


Fig. 1. Location of the Tigray Regional State and the Wukro district, case study area, Northern Ethiopia

The Wukro District is located between 13°14′ and 14°02′ N and 39°34′ and 39°37′ E, and covers a total area of about 100,228 ha (BoARD, 2008) (Fig. 1). It has 63 Kushets (the smallest administrative unit in the area), a total population of 99,688 with 23,899 household heads (FDREPCC, 2008). Based on analysis of climate data obtained from the National Meteorological Services Agency, the mean annual rainfall at Wukro station for the years 1996-2006 was computed at 723 mm. While the mean annual average daily air temperature is 20°C, with mean annual daily minimum and maximum values of 11°C and 28°C, respectively. According to IFSP (1995), the elevation ranges between 1960 and 2600 m.a.s.l. The same report classified the most common soil types of the area into three: Clay (*Baekel*), Red (*Mekayih*) and Black (*Walka*) .

### 2.2 Field layout of the FDI system

The installation of family drip irrigation had the following details:

- Four lateral pipes of 25 m long each with drippers spaced at 0.3m and a 20 m length manifold with laterals fitted along it at a spacing of 0.75m interval were laid out to irrigate an area of 500 $m^2$. The FDI kit contains a water tank, a riser, a manifold, laterals, disc filter, valve, end-cap, and different fittings, where the detailed experimental setup is given in Figure 2;
- The water container was placed at 2m high on a stand made of wooden logs;
- The height of water outlet was at 2.1m since the barrel was drilled at 10 cm above the bottom and a 3/4" socket was welded to it in order to provide the water pressure required to operate the system and to allow suspended materials to settle;
- A 3/4" disc filter was attached to a 3/4" straight adaptor on the barrel;
- On the straight adaptor a 3/4" disc filter was attached. Again a female elbow was connected to a disc filter and to the risers followed by flow regulator up on the manifold at both left and right sides;
- The manifolds having a diameter of 25 mm were laid and connected to the riser at the center, while the riser was connected to the elbow then to the water container;
- The laterals having a diameter of 12 mm were unrolled and laid along the full length of each bed of which plants to be irrigated;
- The laterals were connected with the manifold with the help of connectors at 0.75 m interval;
- The end of the laterals and the manifold were closed with end caps and they were tied at the beginning as well as at the end on wooden pegs to avoid direct soil contact and thus to prevent clogging as a result of back siphoning.

### 2.3 Performance assessment of the FDI system

#### 2.3.1 Uniformity

Uniformity in here referred to what extent the water was uniformly distributed across the irrigated area. This is affected by the water pressure distribution in the pipe network and by the hydraulic properties of the emitters used (Smajstrla et al., 2002).

To measure emitter flow rates, a standard graduated cylinder was used and volume of water was collected for one minute. A stopwatch was used to measure the time. For uniformity determination, measurements were made three times at 32 locations in each FDI kits during the crop growing season taking into consideration the minimum recommended number points by Smajstrla (2002). Care was also taken to distribute the measurement points throughout the irrigated zone. In order to address all these issues, uniformity evaluation procedures developed by FAO (1980) were followed with the following details and also as shown in Figure 3;

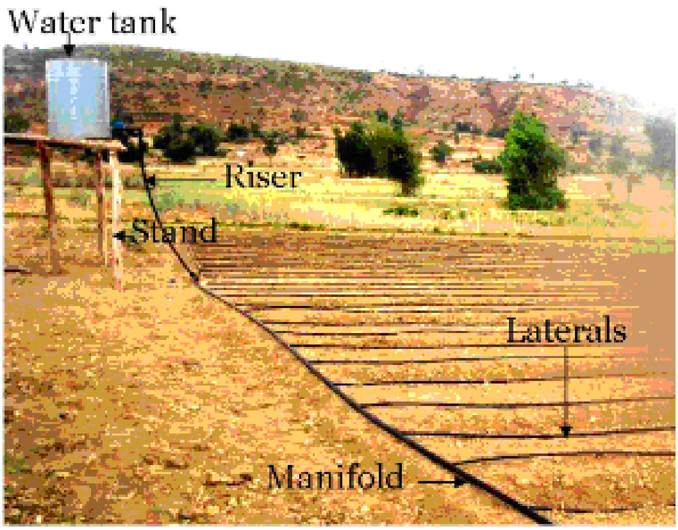


Fig. 2. Detailed experimental set up for the family drip irrigation system of this study

Four laterals were located along an operating manifold; one at the left end of the inlet, one at the right end of the inlet and two located at ½ ways to the right and left from the inlet midpoint;
On each lateral, 2 adjacent emitters were selected at 8 different emitter locations: at the inlet end, 1/3 down way of the lateral, 2/3 down way of the lateral and at farthest end point of the lateral.
Four commonly used uniformity parameters were determined for this study:
The first uniformity parameter used was emission uniformity ($E_U$) which is the most useful system performance indicator for trickle systems. Sometimes in case of field evaluation it is defined as distributions uniformity ($D_U$) which was calculated using Equation 1 (Kruse, 1978).

$$E_u = 100 \times \left( \frac{q_{\min}}{q_a} \right) \quad (1)$$

Where:

$E_U$ = Field emission uniformity (%);
$q_{min}$ = Minimum discharge rate computed from minimum pressure in the system (l/h) and
$q_a$ = average of all field data emitter discharge rates (l/h).

The second uniformity parameter used was emitter flow variation ($q_{Var}$) which was calculated using Equation 2 (Wu, 1983):

$$q_{\text{var}} = \left( \frac{q_{\max} - q_{\min}}{q_{\max}} \right) \quad (2)$$

Where:

$q_{max}$ = maximum emitter flow rate (l/h) and

$q_{min}$ = minimum emitter flow rate (l/h).

The third uniformity parameter used was coefficient of variation ($C_V$) which was calculated using Equation 3 (Wu, 1983).

$$C_v = \frac{S}{q_a} \quad (3)$$

Where:

$S$ = standard deviation of emitter flow rates (l/h) and

$q_a$ = average emitter flow rate (l/h).

The fourth uniformity parameter used was uniformity coefficients (UC) which is often described in terms of the coefficient of variation defined as the ratio of the standard deviation to the mean and was calculated using Equation 4 (ASAE, 1985) expressed as:

$$U_c = \left(1 - \frac{S_q}{q_a}\right) \times 100 \quad (4)$$

Where:

$U_C$ = uniformity coefficient (%);

$S_q$ = average absolute deviation of all emitters flow from the average emitter flow (l/h) and

$q_a$ = average emitter flow rate (l/h).

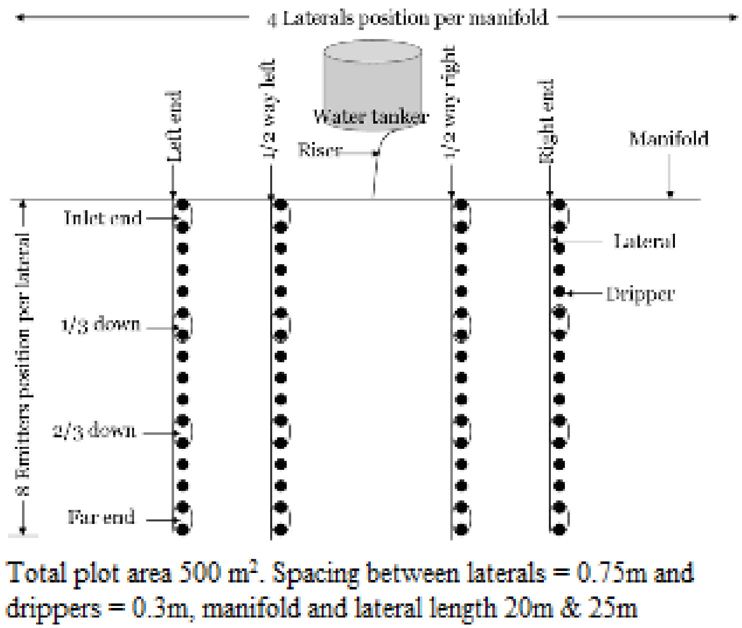


Fig. 3. Layout of control points and discharge measurement for family drip irrigation system of this study

### 2.3.2 Determination of total suspended solids (TSS)

Total suspended solids (TSS) analytical test was employed to determine current or future potential emitters clogging problems arising from poor water quality. Water samples were taken from representative three different shallow wells after operating the motor pump, assumed as the worst case of water physical quality during water delivery moment in time. Taking into consideration the recommendation given by Clesceri et al. (1998) a 250 ml of water samples from each selected shallow wells were taken and oven dried at 105°c for 1 hour at the Soil Physics Laboratory Mekelle University.

The TSS was then calculated using Equation 5 and evaluated based on the Water Quality Guidelines developed by Hanson et al. (1994):

$$TSS = \frac{(A - B) \times 1000}{totalvolume} \tag{5}$$

Where:

A = weight of filter + dried residue (mg), and

B = weight of filter (mg).

### 2.3.3 Evaluation of the water supply-demand for FDI system for selected test crops

Assessment of the existing water supply and the crop water requirements of the two dominantly cultivated crops (onion and tomato) as test crops were done. The total amount of water supplied to each crop throughout the growing season was assessed by multiplying the amount of water applied per irrigation and the frequency of irrigation. The daily volume of water supplied by the farmer to the test crops were taken from farmers' current operation practice. The irrigation frequency was found to be two times per day; one in the morning and the other in evening with total daily supply volume of 0.4m$^3$ water. Taking into account reference evapo-transpiration ($ET_o$), crop type, length of growth, growth stage and effective rainfall, gross irrigation requirement was computed for the two test crops. An average daily $ET_o$ 5.12 mm/day as determined by Haftay (2009) was used for this study. The crop water requirement for the two test crops was estimated by applying Equation (6) given as:

$$ET_c = (ET_o \times K_c) \tag{6}$$

Where:

$ET_c$ = crop evapotranspiration;

$ET_o$ = reference evapotranspiration and

$K_c$ = crop coefficient values which were adapted from Doorenbos and Pruitt (1977).

The net irrigation requirement (NIR) was computed using Equation 7 given as:

$$NIR = (ET_c - P_e) \tag{7}$$

Where:

$ET_c$ = crop evapotranspiration and

$P_e$ = effective rainfall.

Gross irrigation requirement (GIR), which is defined as the depth or volume of irrigation water required over the whole cropped area excluding contributions from other sources, plus water losses and /or operational wastes was estimated using Equation 8 (FAO, 1980) as:

$$GIR = \left(\frac{NIR}{E_a}\right) \quad (8)$$

Where:

GIR = gross water requirement and

$E_a$ = the application efficiency, assumed to be 90% as an attainable value of application efficiency for drip irrigation.

### 2.4 Assessment of FDI kits dissemination trend and adoption Status

To understand the adoption and dissemination status across the region, it was essential to know the spatial and temporal distribution of the system first . For this, a list of distributed family drip irrigation kits over the period of 2004-2008 was obtained from the Tigray Regional Bureau of Agriculture and Rural Development (BoARD), the Tigray Bureau of Water Resource Development (BoWRD) and the Relief Society of Tigray (REST), local development organizations operating in irrigation development in the region. Furthermore, the records obtained from the three Bureaus were organized based on spatial and temporal sequences. In addition, the delivered FDI kits were identified as installed and uninstalled to understand their working conditions.

While for analysis of FDI adoption status and rate, a three-stage sampling techniques were employed to collect data. Accordingly, random samples of 120 household heads were selected from three sites (*Tabias*). Each site consisted of 40 randomly selected respondent farmers from both users and non-users of FDI technology. Besides this, a two-part questionnaire was developed. The first questionnaire consisted of project structural evaluation based on attitudinal or knowledge statements about FDI technology, with possible responses and explanations by the respondent farmers. While the second questionnaire consisted of questions dealing with demographic, education level, age, and source of water and related characteristics of the respondents to identify and analyze variables that were supposed to influence FDI technology adoption. The content of the questionnaire was designed using inputs from staff members of the governmental and non-governmental organization, especially working with the FDI system technology including FDI user farmers. Rejection and inclusion of the variables was made based on the required expected frequency and related criteria as suggested by Rangaswamy (1995). Finally, the adoption status and rate were analyzed using a Chi-square test statistics of the contingency table at significance levels of $P< 0.05$ and 0.01.

## 3. Results and discussion

### 3.1 Performance assessment of the FDI system

#### 3.1.1 Uniformity

The uniformity parameters (emission uniformity, flow variation, and uniformity coefficient) values of the three selected FDI systems are given in Table 1. The average $E_U$ values for the selected FDI systems were 93.67%, 93.85% and 94.34% respectively (Table 1). The emission uniformity obtained from the experiment were found better as compared to the findings by Polak and Sivanappan (2004), for low-cost drip systems using holes made with a heated punch as emitters that reported uniformity rate of 85%. While systems using micro-tubes had uniformity rates of approximately 90%. According to ASAE (1985) standards and other experimental results of FAO (1984), on the general criteria for emission uniformity, emission uniformity greater than 90% is characterized as an excellent range of performance.

A flow variation ($q_{var}$) values of 6.8%, 6% and 5% were obtained for $FDI_1$, $FDI_2$ and $FDI_3$ respectively. According to Braltes (1986), general criteria for emitter flow variation gives as <= 10% desirable, 10-20% acceptable and >20% unacceptable ranges. Thus, this field-based result showed that the performances of all the three FDI system observations were within the desirable range of recommendation which were having less than 10% emitter flow variation. Moreover, a mean coefficient of variation (CV) for flow variation ($qv_{ar}$) values of 0.34, 0.27 and 0.17 were obtained for $FDI_1$, $FDI_2$ and $FDI_3$respectively. This indicated that the results obtained in this experiment were marginal to unacceptable for $FDI_1$ and average for $FDI_2$ and $FDI_3$ based on the guidelines set up by the American Society of Agricultural Engineers ASAE (1985).

Average uniformity coefficient (Uc) values of 73%, 97% and 98 % were obtained for $FDI_1$, $FDI_2$ and $FDI_3$ respectively. These values indicate that $FDI_2$ and $FDI_3$ systems were found to have a uniformity coefficient values rated as excellent (> 90%), but the uniformity coefficient value for $FDI_1$ was below 85%, which was considered as rationally bad range of performance as suggested by Malik et al. (1994).

In general the different aspects of the FDI uniformity indexes used in this study revealed that the FDI technology has no as such significant problem in relation to non-uniform water distribution within the field.

| $FDI_1$ | parameters | | | |
|---|---|---|---|---|
| observed | $E_{U\,(\%)}$ | $q_{Var\,(\%)}$ | $C_{V(ratio)}$ | $UC_{(\%)}$ |
| Beginning | 94.04 | 5.00 | 0.21 | 99.79 |
| Middle | 93.91 | 8.50 | 0.54 | 46.00 |
| End | 93.06 | 7.00 | 0.26 | 74.00 |
| $FDI_2$ | | | | |
| Beginning | 94.05 | 3.00 | 0.02 | 98.00 |
| Middle | 95.14 | 10.00 | 0.02 | 98.00 |
| End | 92.35 | 5.00 | 0.04 | 96.00 |
| $FDI_3$ | | | | |
| Beginning | 95.17 | 3.00 | 0.01 | 99.00 |
| Middle | 94.74 | 7.00 | 0.02 | 98.00 |
| End | 93.12 | 5.00 | 0.02 | 98.00 |

Eu: Emission uniformity; $q_{Var:}$ Flow variation; $C_{V:}$ Coefficient of variation; $U_{C:}$ Uniformity coefficient.

Table 1. Uniformity parameter values of the three selected FDI systems

### 3.1.2 Total suspended solids (TSS) and emitter clogging hazards

Results of the TSS analytical test showed 144, 116 and 96 mg/l for shallow wells 1, 2 and 3 respectively (Table 2). According to Water Quality Guideline for micro irrigation developed by Haman et al. (1987), the TSS results in this study fall in a moderate to severe grounds for emitter clogging hazards. As shallow wells 1 and 2 are where a severe clogging problem is likely to occur it calls for pre-filtration or improve filtration mechanisms within the system before emitter plugging hazard occurs.

| Pan No | Sample code | Mass pan+ filter (gm) | Volume of water sample (ml) | Mass pan+ filter + TSS (gm) | mass TSS (gm) = [e-c] | TSS (mg/L)= [f/d] x $10^6$ |
|---|---|---|---|---|---|---|
| a | b | c | d | e | f | g |
| 1 | shallow well 1 | 2 | 250 | 2.036 | 0.036 | 144 |
| 2 | shallow well 2 | 2 | 250 | 2.021 | 0.029 | 116 |
| 3 | shallow well 3 | 2 | 250 | 2.024 | 0.024 | 96 |

Table 2. Total suspended solids (TSS) for the three shallow wells.

### 3.1.3 Evaluation of the water demand and supply for FDI system

The estimated total water requirements for onion and tomato were 315 $m^3$ and 180 $m^3$ while the corresponding total water supply was 120 $m^3$ and 96 $m^3$ respectively. Furthermore, the daily water demand for plot size of 500 $m^2$ is 2.1 $m^3$ for onion and 1.53 $m^3$ for tomato (Table 3).

From this result, the farmers need to apply the required quantity of water for the crop, and for that they need to be aware of the supply-demand relationships through organizing demonstrations and trainings. In case, labor availability is a problem to cover the entire area, they may reduce the size of the irrigated plot from 500$m^2$ to 190 $m^2$ for onion and 27 $m^2$ for tomato, respectively. Failure to supply the required amount of water to the crop would result in a significant yield reduction, which could eventually force the farmers to abandon the use of FDI system technology.

| crop Type | D.W.R (mm/d) | G.W.R ($m^3$/A) | T.W.R ($m^3$/A) | Area ($m^2$) | D.W.S (mm/d) | T.W.S ($m^3$/A) | Deficit ($m^3$/A) | Deficit (%) |
|---|---|---|---|---|---|---|---|---|
| Onion | 4.14 | 2.1 | 315 | 500 | 0.8 | 120 | -195 | 61.9 |
| Tomato | 3.06 | 1.53 | 183.6 | 500 | 0.8 | 96 | -87.6 | 52.28 |

D.W.R: Daily water requirement; D.W.S: Daily water supply; T.W.S: Total water supply; G.W.R: Gross water requirement; d: Day ; A: Area.

Table 3. Comparison of water demand and supply for Onion and Tomato crops.

### 3.2 Assessment of FDI kits dissemination trend and adoption status

#### 3.2.1 Distribution trends of FDI system kits

Figures 4 & 5 show that the distribution of FDI kits has shown increasing trend both across the years and zones. However, sites assessment results showed that, there was a variation in FDI kit supply within a given time and place in all Zones of the region. Analysis of the distribution records in the past 5 years (2004-2008) shows that, the maximum FDI kit distribution was observed in year 2008. The established factory that is producing the equipment required for drip irrigation system may have a significance contribution in maximizing the temporal and special distribution trends of the technology.

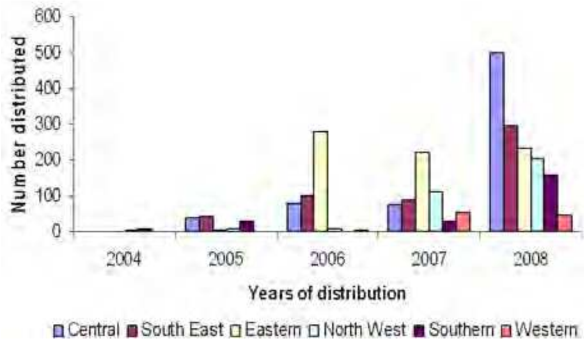


Fig. 4. Temporal distribution trend of FDI system at zonal Level of the Tigray Regional State, Northern Ethiopia

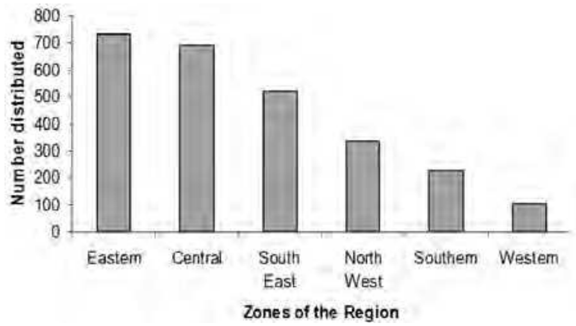


Fig. 5. Spatial distribution trend of FDI system at zonal level of the Tigray Regional State, Northern Ethiopia.

However, the number of working (installed) FDI Kits throughout region were only 1442 out of the 2615 supplied (i.e. 55 %). There is high spatial variation among the zones in the region which ranges between 20 % in Southern Zone to 84 %, in Southeast Zone (Figure 5). However, In Wukro district where this study was conducted, 100% the delivered FDI Kits were installed in the field (Figure 6). This shows that Southeast Zone relatively attained the satisfactory results in-terms of installing the delivered FDI kits at zonal level. Based on the findings, discussions and communications (formal and informal) held with beneficiaries, stakeholders, experts and administrators at different managerial levels during and between the assessments of FDI trends, those areas with low achievement of FDI installation were characterized by inadequate extension services, supervisions and monitoring the operational progress and low involvement of non-governmental organizations (NGOs). Since, the involvement of NGOs both in application of technique and operation of the delivered FDI kits might be their own contribution during the installation.

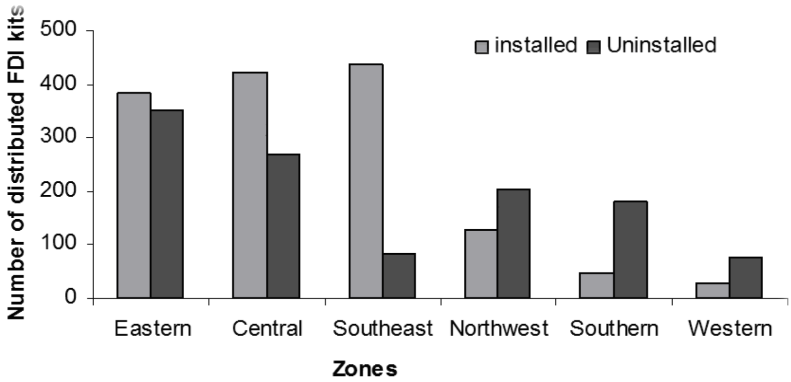


Fig. 6. FDI system distribution zones of the Tigray Regional State, Northern Ethiopia.

Conversely, the study area has no problem of installation for the delivered FDI kit. Though, extension services, monitoring and other related activities may have less importance, however, like other areas of the region, there is still variability in both temporal and spatial distribution of FDI system kits (Figures 7 & 8). Yet, there are two sites (Kihen and Debreberhan) among the 15 studied sites where FDI system intervention was absent.

In majority of the cases in the study area (District), sites (*Tabias*) with low to nil FDI system intervention were located outside of the main road of the District. These areas are also characterized by inadequate infrastructures such as access to roads, extension services, marketing outlets that attributed to the slow pace of FDI dissemination in the study area.

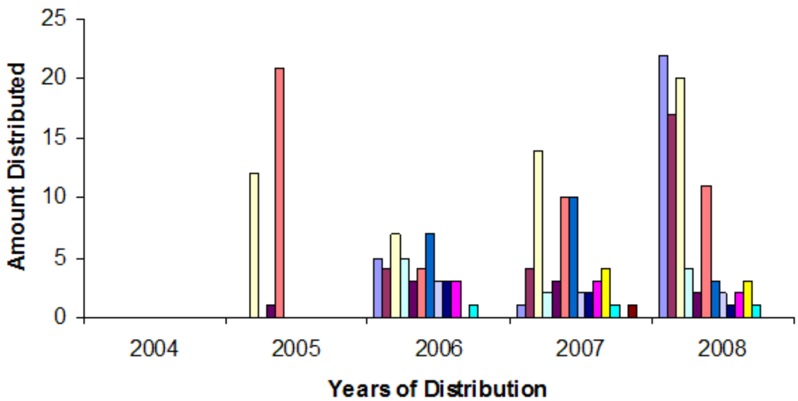


Fig. 7. Temporal Distribution Trend of FDI kit for 15 *Tabias* of Wukro Woreda in Tigray Regional Sate, Northern Ethiopia

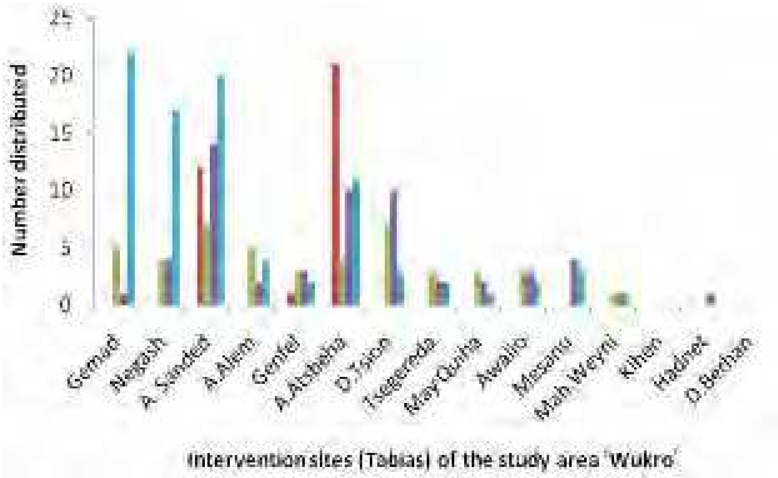


Fig. 8. Spatial Distribution Trend of FDI kit for 15 *Tabias* of Wukro Woreda in Tigray Regional Sate, Northern Ethiopia

### 3.2.2 Factors controlling adoption of FDI system

#### 3.2.2.1 Age group and adoption status

Age group was found to influence the FDI adoption rate significantly ($P< 0.05$; Table 4). Younger farmers (30-45 years of age) were found relatively better adopters of FDI technology than older ones as the latter were not convinced with the significance of water drops to satisfy crop needs as compared to the one traditionally used furrow irrigation.

| Age group | FDI adoption status | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Current users | | Current non-users | | Future users | | Total | |
| | No | (%) | No | (%) | No | (%) | No | (%) |
| 30-45 | 20 | 54.1 | 9 | 24.3 | 8 | 21.6 | 37 | 100 |
| 46-60 | 10 | 37.1 | 8 | 29.6 | 9 | 33.3 | 27 | 100 |
| 60&above | 8 | 14.3 | 40 | 71.4 | 8 | 14.3 | 56 | 100 |
| Total | 38 | 31.7 | 57 | 47.5 | 25 | 20.8 | 120 | 100 |

Table 4. Age group and FDI adoption status

#### 3.2.2.2 Education level and FDI adoption status

Education level was found to influence adoption rate significantly ($P < 0.05$; Table 5). Farmers with exposure to primary school (grades 1-6) were found dominant adopters of FDI technology. Uneducated farmers were the lowest adopter. Therefore, in order to expand FDI technology utilization it would be sound to work with literate farmers in general and grade 1-6 in particular.

| Education level | FDI adoption status | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Current Users | | Current non-users | | Future users | | Total | |
| | No | (%) | No | (%) | No | (%) | No | (%) |
| Non-educated | 9 | 18.8 | 30 | 62.5 | 9 | 18.7 | 48 | 100 |
| 1- 6 grade | 19 | 42.2 | 9 | 20.0 | 17 | 37.8 | 45 | 100 |
| Grade 7 & above | 10 | 37.0 | 10 | 37.0 | 7 | 26.0 | 27 | 100 |
| Total | 38 | 31.7 | 49 | 40.8 | 33 | 27.5 | 120 | 100 |

Table 5. Education level and FDI adoption status

**3.2.2.3 Access to water source type and FDI adoption status**

Farmers having access to shallow well water source were found better adaptors of FDI technology as compared to farmers having access to surface water source ($P < 0.01$; Table 6). This variability in adoption rate of the technology is related to the location of the water sources in relation to homesteads that made it easy to follow-up and manage the farm. Moreover, using shallow wells as source of water for FDI technology is relatively secured from vandalism of FDI kits because of the relative advantage being nearer to homesteads with that of surface water sources.

| Water source | FDI users | | FDI non-users | | Total | |
|---|---|---|---|---|---|---|
| | No | (%) | No | (%) | No | (%) |
| Ground | 31 | 83.8 | 6 | 16.2 | 37 | 100 |
| Surface | 7 | 8.4 | 76 | 91.6 | 83 | 100 |
| Total | 38 | 31.7 | 82 | 68.3 | 120 | 100 |

Table 6. Access to water source and FDI adoption status

**3.2.2.4 Gender and FDI adoption status**

Female-headed households were found better adopters of the FDI technology as compared to male-headed household heads though not significantly different (Table 7). The better adoption rate of female household heads may arise from their access to work around their homestead for long time. Moreover, the provision protocol of FDI kits encourages female household heads.

| Sex | FDI users | | FDI non users | | Total | |
|---|---|---|---|---|---|---|
| | No | (%) | No | (%) | No | (%) |
| Female | 10 | 40.0 | 15 | 60.0 | 25 | 100 |
| Male | 28 | 29.5 | 67 | 70.5 | 95 | 100 |
| Total | 38 | 31.7 | 82 | 86.3 | 120 | 100 |

Table 7. Gender and FDI adoption status

## 4. Conclusions

Household family drip irrigation technology has been introduced recently in the Tigray Regional State as an option to conserve water and hence to increase crop production in the region. This study evaluated its performance on the basis of various performance indicators.

Average uniformity coefficient values of 73 %, 97 % and 98 % were obtained for $FDI_1$, $FDI_2$ and $FD_3$ respectively. Based on ASAE (1985) criteria, the results obtained in this experiment were marginal to unacceptable for $FDI_1$, but good for $FDI_2$ and $FDI_3$. The clogging hazard was moderate to severe under current operation conditions of the FDI system, which may add up on the cost of spare parts and would likely to reduce the adoption rate by farmers. Therefore, regular inspection of emitters to identify clogged ones and undertaking of routine maintenances are necessary. Dismantling, blowing in it, or flashing out with water could help maintaining a clogged emitter. If, the situation is more serious, it is better to change the emitters. On-line type of emitter is more favorable than in-line ones because on-line emitters can be dismantled and repaired easily by the farmer. Frequent inspection and cleaning of filter is also more important.

Under the existing FDI operating condition, the supplies of water for the crops were very low to satisfy their demand. This indicates that, farmers and extension workers have limited knowledge and perception about the FDI technology operation systems. Thus, the users and development workers may need further training and demonstration of the technology at field level under farmers' operating condition. Moreover, appropriate technical and agronomic guidance and support to farmers in development and introduction of drip sets to sustain adopter's motivation throughout the season are needed.

The result of this field-based study revealed that the lower growth of FDI system utilization is not associated with the technology itself but it is rather due to the lack of awareness by the farmers and development agents on the technical and operational requirements of the FDI system to effectively operate and utilize the technology at household level.

Therefore extension services to raise awareness on the utilization and management, and mechanisms to monitor the development FDI technologies implementation should be strengthened. Moreover, further study is still needed to analyze the economic feasibility of the FDI system.

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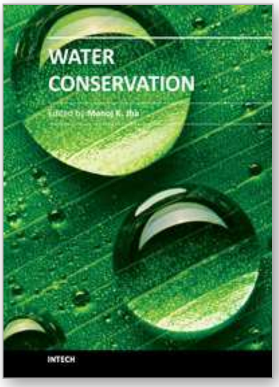


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Water is an essential and basic human need for urban, industrial and agricultural use. While an abundance of fresh water resources is available, its uneven distribution around the globe creates challenges for sustainable use of this resource. Water conservation refers to an efficient and optimal use as well as protection of valuable water resources and this book focuses on some commonly used tools and techniques such as rainwater harvesting, water reuse and recycling, cooling water recycling, irrigation techniques such as drip irrigation, agricultural management practices, groundwater management, and water conservation incentives.

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