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*Full Length Research Paper*

# Effect of drip lateral spacing and mulching on yield, irrigation water use efficiency and net return of onion (*Allium cepa L.*) at Ambo, Western Shoa, Ethiopia

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**Field experiment was conducted at Ambo during the 2017/2018 to investigate effects of drip lateral spacing and mulching on yield, water use efficiency and net return of onion. Eight treatments with three replications were randomized in complete block design to conduct the experiment. Two levels of drip lateral spacing and four levels of mulch were used to evaluate their effects. The result showed that both onion yield and water use efficiency were affected by main effects of drip lateral spacing and mulching but not affected by their interaction effect. The maximum bulb yield 34990 and 35117 kg ha$^{-1}$ of onion were recorded from onion grown under drip lateral in every row and white plastic mulching, respectively. Water use efficiency of 1.14 and 1.15 kg L$^{-1}$ were recorded from onion grown under drip lateral spacing in every row and white plastic mulching, respectively. Even though white plastic mulch scores significantly higher yield and water use efficiency, highest net returns of 246,410 and 284,616 ETB ha$^{-1}$ were obtained from drip laterals in every rows and no mulch, respectively. This suggests that drip laterals in every rows and no mulching is economically feasible for drip irrigated onion production at Ambo.**

**Key words:** Drip irrigation, drip lateral spacing, mulching, bulb yield, water use efficiency, net return, Ambo woreda.

## INTRODUCTION

Irrigation water, limited information and cost of production are the most limiting factor for irrigated vegetable production in areas where rainfall is unevenly distributed temporary and spatially. Vegetable crops are consumed in either raw or cooked form. The edible portion may be a root, a tuber or storage stem, a bulb, leafstalk, leaf, an immature flower, a seed, the immature fruit and mature fruit. They play an important role in contributing to the household food security. At present, following tomato, onion (*Allium cepa L.*) is one of the most popular vegetables in the world (FAO, 1999). Ethiopia has a great potential to produce onion every year for both local consumption and export with an average yield of 13.3 tones/ha which is below world average production (CSA,

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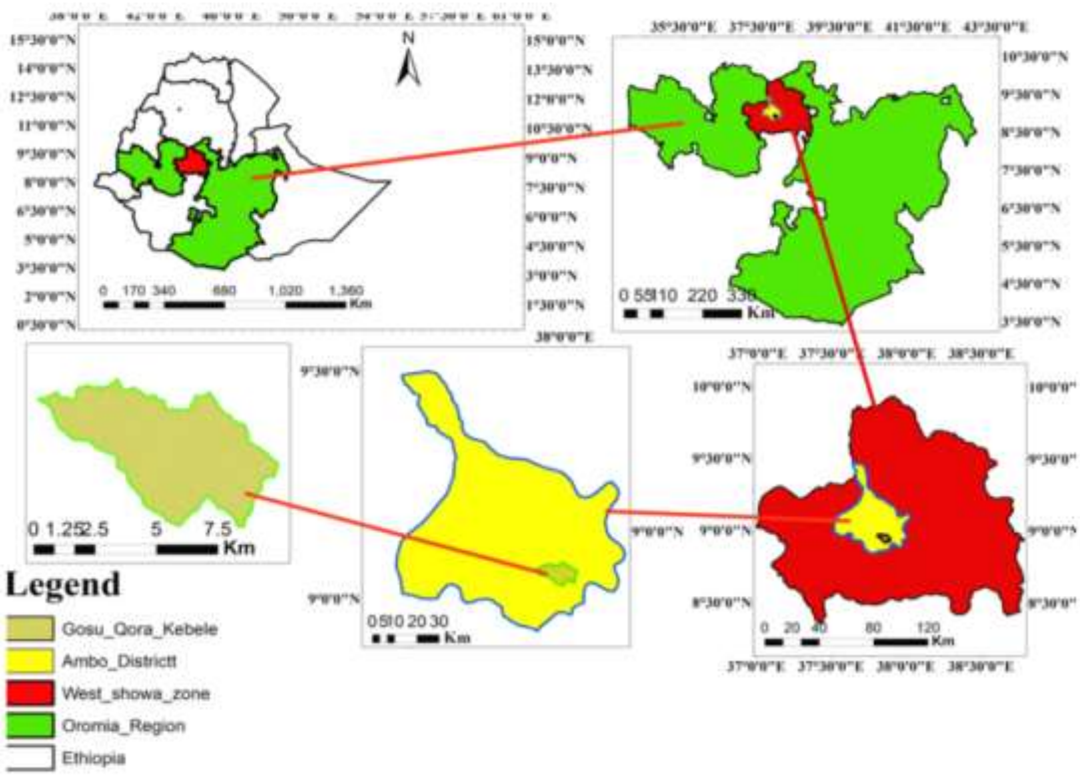


**Figure 1.** Map of the study area.

2001/2002 as cited in Taha, 2007).

Farmers in the study area produce vegetable crops especially onion two times per dry season using traditional furrow irrigation method for their consumption and market. But lack of modern irrigation system, poor irrigation water management practices and lack of modern technologies and farm land production and productivity is very low. Loss of farm land, less net return income and un-optimized irrigation production were the created conflict among irrigators. A number of researches have been done to evaluate performance of drip irrigation practices in this country. However, none of these researches have attempted to evaluate the combined effects of drip lateral spacing and mulching on onion production in the study area. Therefore, the experiment was conducted to evaluate the feasibility of drip lateral spacing and mulches for onion cultivation in terms of yield, water use efficiency and economics for improving crop and irrigation water productivity in drip irrigated agriculture.

## MATERIALS AND METHODS

### Description of study area

The experiment was conducted at West Shoa Zone, Ambo Woreda in Ambo Agricultural Research Center Farm site from October 2017 to May 2018. The geographical location is 37.5135°E and 08. 5816°N with an altitude of 2144 m a.s.l. The area is about 115 km from Addis Ababa. Mean annual precipitation of 1029 mm and the mean temperatures of the area range from 26.4 and 10.3°C. Its soil texture is clay (Figure 1).

### Experimental design

The experiment was a two factor factorial experiment arranged in RCBD with three replications. The two factors were drip lateral spacing and mulch types. The drip lateral spacing was 2 levels and mulch types were 4 levels. The sizes of experimental plots were 3×1.2 m with 8 plots per each replication with inter-row 30 cm and intra-row spacing of 10 cm with 4 plant rows per each plot (Figures 2 and 3).

### Application of mulch

Wheat straw mulch was applied uniformly to the experimental plots at the layer of 10 cm depth and at 15 days after transplanting (Michael, 2013). Black and White Plastic mulch treatments of 1.5 mm thick were applied over the ground surface of experimental plots at 15 days after transplanting.

### Irrigation water application procedure

The experiment water from Huluka river was conveyed from river to the experimental site through lined canal and diverted to the field through unlined canal. Water was collected into the barrel manually to irrigate the experimental plot. Crop water requirement of onion

**Figure 2.** Field layout of the study area.

**Figure 3.** Field layout of family drip irrigation system.

crop during different growth stage was computed by CROPWAT8.0 software. Climate data of the study area, test crop data and soil data were used to compute crop evapotranspiration (ETc). The frequency and duration of irrigation was determined using FAO (1998).

### Drip installation procedure

Overhead barrel system was used to supply water to the system. The barrel was constructed 1.5 m above the ground from locally available wood and ¾" socket was welded onto it at 5 cm above its bottom. A mainline with a diameter of 25 and 20 mm was connected to the drain outlet. Manifold of 16 mm was connected to main line. The size of lateral was 16 mm, and dripper spacing was 30 cm. The laterals were connected to the manifold at 0.60 m for drip lateral between two onion rows and 0.30 m for that of drip lateral in every onion plant rows.

### Test crop management

An onion seed of "Adama Red" variety was used as test crop from Melkas Agricultural Research Center. The seeds were sown in the well prepared nursery seed bed field on 1st January 2018. The seedlings were transplanted onto the experimental plots on 16th January 2018. The recommended fertilizers rates of 150 kg/ha for Urea and 200 kg/ha for TSP were applied during transplanting in this experiment (Getachew et al., 2011). Amount of fertilizer applied per each plot was calculated from the recommended fertilizer rate. 0.054 kg of Urea and 0.075 kg of TSP were applied for the 3.6 $m^2$ experimental plot at the time of transplanting. Hand weeding was used to control weeds. The data of yield and total amounts of water applied were used to evaluate the effects of drip lateral spacing and mulching on onion crop and water use efficiency.

### Yield data collection

The test plant was up rooted from two central rows of each plot at its optimum maturity (June 6th) and it was field dried for 5 days under sunny conditions (George et al., 2014). After it was dried the bulb yield was cut from its above ground plant part and the weight of its bulb yield was taken and converted to hectare base and bulb yield per hectare (kg $ha^{-1}$) was used for the analysis to determine effects of drip lateral spacing and mulching on bulb yield.

### Water use efficiency

Onion crop water-use efficiency was determined in terms of marketable bulb yield produced per unit volume of water. It was calculated from the ratio of mean weight of bulb yield to that of total volume of water consumed. And the values were used for analysis. Water use efficiency was calculated using Equation 1 (Oweis and Zhang, 1983) as:

$$WUE = \frac{Y}{ETa} \quad (1)$$

where WUE = water use efficiency (kg $m^3$), Y= yield of onion (kg), and ETa = actual evapotranspiration (mm).

### Economic analysis

Economic analysis of the experiment was analyzed by taking the

**Table 1.** Main effects of drip lateral spacing on onion yield.

| Treatment | YD (kg $ha^{-1}$) | WUE (kg $L^{-1}$) | BM (kg $ha^{-1}$) | PH(cm) | PP | BD (cm) | HI (%) |
|---|---|---|---|---|---|---|---|
| DLER | $34990^a$ | $1.14^a$ | 37769 | $57.97^a$ | 119 | $7.99^a$ | $92.63^a$ |
| DLBTR | $30230^b$ | $0.99^b$ | 35277 | $50.32^b$ | 119 | $6.24^b$ | $85.80^b$ |
| LSD (%) | 2437.1 | 0.079 | Ns | 1.96 | Ns | 0.9 | 1.37 |
| CV (%) | 8.54 | 8.49 | 8.35 | 4.13 | 1.41 | 6.22 | 1.75 |

YD = Bulb yield, BM = biomass, WUE = water use efficiency, PH = plant height, PP = plant population, BD = bulb diameter, HI = harvest index, DLER = drip lateral in every row, DLBTR = drip lateral between two rows, LSD (%) = least significant Difference at 5% of significance, CV (%) = coefficient of variation, ns = no significant difference.

average of three years cost of drip lateral, mulching cost and manpower cost for weeding, drip lateral installation and mulching and removal. Each cost was calculated for each treatment separately. The mean bulb yield (kg $ha^{-1}$) was adjusted for yield losses by subtracting 10% of the bulb yield from total yield. The total net return was calculated by multiplying bulb yield with its production cost separately for each treatment. It was determined using partial budget analysis (Equations 2, 3, and 4):

$$TR=Y\times P \quad (2)$$

$$NI=TR-TC \quad (3)$$

$$TC=FC+VC \quad (4)$$

where TR = total return, Y = crop yield, P = unit price, NI = net income, TC = total cost, FC = fixed cost, and VC = variable cost.

### Data analysis

In order to evaluate main effects of drip lateral spacing and mulching on onion bulb yield and water use efficiency data of yield components, cost of production and water applied were collected. The data were subjected to ANOVA using SAS 9.0 software with significance level p ≤ 0.05. LSD test was applied for statistically significant parameters to compare means among the treatments (Steel and Torrie, 1980).

## RESULTS AND DISCUSSION

### Main effects of drip lateral spacing on onion yield and water use efficiency

The summarized mean values of bulb yield of onion shown in Table 1 showed that there was significant (P ≤ 0.05) difference on mean bulb yield of onion, water use efficiency, plant height, bulb diameter and harvest index due to main effects of drip lateral spacing. Significantly higher bulb yield of 34990 kg $ha^{-1}$ onion was recorded from onion grown under drip lateral in every row and the lowest bulb yield was recorded from onion grown under drip lateral spacing between two rows (30230 kg $ha^{-1}$). Bulb yield was reduced by 13.6% when drip lateral between two rows were used. This result is in agreement with finding of Solomon et al. (2013) reporting drip lateral spacing in every row yields more. Similarly, Himanshu et al. (2012) reported the highest mean marketable bulb yield of onion was recorded from lateral spacing in every row. On the contrary, Wondatir et al. (2013) discussed that the highest marketable bulb yield was obtained due to the effects of 1 m drip lateral spacing and the lowest were obtained due to the effects of 0.5 m drip lateral spacing. Effects of drip lateral spacing on bulb yield and yield components of onion is discussed in terms of its effect on availability of irrigated water for plant roots. Drip lateral spacing in every row was irrigated near the root zone of onion as compared to that of drip laterals between two onion plant rows. Because drip laterals installed at 0.6 m apart from the plant (drip laterals between two rows) cause onion plant roots unable to extract the water as it drips beyond the root zone.

The highest water use efficiency of 1.14 kg $L^{-1}$ was recorded from onion grown under drip lateral spacing in every row and the lowest water use efficiency (0.99 kg $L^{-1}$) was recorded from onion grown under drip lateral spacing between two rows. The mean value of biomass and plant population showed non-significant (p ≤ 0.05) difference due to the main effect of drip lateral spacing (Table 1).

In case of plant height and bulb diameter, mean values have shown significant (P ≤ 0.05) difference due to main effect of drip lateral spacing (Table 1). The highest mean value of plant height (57.97 cm) was recorded from onion grown under drip lateral in every rows and the lowest mean value (50.32 cm) was from onion grown under drip laterals between two rows. Bulb diameter of 7.99 and 6.24 cm were recorded from onion grown under drip lateral spacing in every row and drip lateral between two rows, respectively. Harvest index also showed significant difference (P ≤ 0.05) due to the main effects of drip lateral spacing (Table 1). The highest mean value of 92.63% harvest index was recorded from onion grown under drip laterals in every row and the lowest mean value of 85.80% harvest index was obtained from drip lateral between two rows. The highest yield component results under drip lateral spacing in every row were due to the highest water use efficiency observed from the treatment.

**Table 2.** Main effects of drip lateral spacing on onion yield.

| Treatment | YD (kg ha$^{-1}$) | WUE (kg L$^{-1}$) | BM (kg ha$^{-1}$) | PH (cm) | PP | BD (cm) | HI (%) |
|---|---|---|---|---|---|---|---|
| NM | 31795$^{bc}$ | 1.04$^{c}$ | 37119 | 53$^{bc}$ | 119 | 6.22$^{b}$ | 85.66$^{c}$ |
| WSM | 32498$^{b}$ | 1.06$^{b}$ | 35352 | 55$^{b}$ | 119 | 6.00$^{b}$ | 91.82$^{b}$ |
| WPM | 35117$^{a}$ | 1.15$^{a}$ | 36949 | 51$^{c}$ | 118 | 7.18$^{a}$ | 95.04$^{a}$ |
| BPM | 32030$^{b}$ | 1.05$^{c}$ | 36672 | 57$^{a}$ | 119 | 6.16$^{b}$ | 87.33$^{c}$ |
| LSD (%) | 2520 | 0.08 | Ns | 1.77 | Ns | 0.8 | 1.94 |
| CV (%) | 8.54 | 8.49 | 8.35 | 4.13 | 1.41 | 4.13 | 1.75 |

YD = Bulb yield, WUE = water use efficiency, PH = plant height, BD = bulb diameter, HI = harvest Index, PP = plant population, NM = no mulch, WSM=wheat straw mulch, WPM=white plastic mulch, BPM=black plastic mulch, LSD (%) = least significant difference at 5% of significance, CV (%) = coefficient of variation, ns=non-significant at 5% probability level.

**Main effects of mulching on onion yield and water use efficiency**

Bulb yield of onion has shown significant ($P \leq 0.05$) difference due to the main effects of mulching (Table 2). The highest mean bulb yield of 35117 kg ha$^{-1}$ was obtained from white plastic mulch and the lowest (31795 kg ha$^{-1}$) was from no mulch. But there is no significant ($P \leq 0.05$) difference in bulb yield between no mulch, wheat straw mulch and black plastic mulch treatment. This result indicates that white plastic mulch has 9.5% yield advantage than no much, wheat straw mulch and black plastic mulch treatment (Table 2). Similarly, Vavrina and Roka (2000) also reported that the benefits associated with the use of plastic mulches for vegetable production include higher yields, earlier harvests, improved weed control, cleaner fruit and increased efficiency in the use of water and fertilizers. The mean values of water use efficiency showed significant ($P \leq 0.05$) difference due to the main effects of mulching (Table 2). The highest mean value of water use efficiency of 1.15 kg L$^{-1}$ was recorded from white plastic mulch and the lowest score of 1.04kg L$^{-1}$ was from no mulch treatments. The mean values of plant height, bulb diameter and harvest index showed significant ($P \leq 0.05$) difference due to the main effects mulching. The highest mean value of plant height of (57 cm) was recorded from black plastic mulch and the lowest (51 cm) was from white plastic mulch. In case of bulb diameter, the highest mean value of bulb diameter of 7.18 cm onion was recorded from onion grown under white plastic mulch and the lowest mean values of bulb diameters (6, 6.16 and 6.22 cm) was recorded from onion grown under wheat straw, black plastic and no mulches, respectively. The highest mean value of 95.04% harvest index was recorded from white plastic mulch and the lowest (85.66%) score was from no mulch. This is due to the highest mean bulb yield obtained from white mulch. The mean value of biomass and plant population showed non-significant ($p \leq 0.05$) difference due to the main effect of drip lateral spacing and mulching (Table 2). Researchers have demonstrated that in comparison to not mulched soil, the crop yields of mulched soils (depending on factors such as geographic location, soil type and nature of mulch) can be enhanced two or three folds in vegetables (Pollack et al., 1969; Bhella, 1986). Bulb size under white plastic mulch treatment was significantly larger than in the other treatments. It is apparent that the large size of bulbs translated into heavy bulbs and enhanced bulb yield. White plastic mulch affects not only bulb size, but also attractive in color and shape. There are many reports confirming the stimulation of growth and consequent yield increases by the use of plastic mulches. Plastic mulches substantially reduce evaporation of water from the soil surface especially under trickle/drip irrigation (Anusuya and Betsy, 2001). Among its advantages in use is increase in soil temperature, reduced fertilizer leaching, reduced evaporation, cleaner product and reduced weed problems. Vavrina and Roka (2000) also reported that the benefits associated with the use of plastic mulches for vegetable production include higher yields, earlier harvests, improved weed control, cleaner fruit and increased efficiency in the use of water and fertilizers. Mulches may increase or decrease root zone temperature, depending on how the mulch affects the energy balance of the soil (Liakatas et al., 1986). Black plastic mulch resulted in the highest root zone temperature, which is consistent with numerous reports that show root zone temperature under black plastic mulch may be at least 2°C higher as compared to bare soil (Diaz-Perez and Batal, 2002; Lamont, 1993). No consistent differences in root zone temperature between bare soil and straw mulch. Total yield, marketable yield, total number of bulbs and weight of individual bulbs increased with increasing seasonal root zone temperature up to an optimum at 15.8°C, followed by reductions in yields and individual bulb weight at >15.8°C (Juan et al., 2004).

The extent of the increase in soil temperature depends on the color of the film and the intensity of solar radiation. The other advantage associated with plastic mulch is that, the movement of water is directed upwards in soil

**Table 3.** Interaction effects of drip lateral spacing and mulching on onion yield and water use efficiency of onion.

| Sources of variation | DF | Mean square | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Bulb yield (kg ha$^{-1}$) | WUE (kg L$^{-1}$) | Biomass (kg ha$^{-1}$) | Plant height (cm) | Plant population | Bulb diameter (cm) | HI (%) |
| Replication | 2 | 33181552.2 | 0.0351125 | 50598550.7 | 12.6467 | 1.04167 | 0.13013 | 5.90975 |
| Drip lateral spacing | 1 | 135929733.8* | 0.14726667* | 37250416.7 | 351.135* | 0.375 | 0.38506667* | 280.059467* |
| Mulching | 3 | 6566.12.9* | 0.00664444* | 3862280.5 | 33.521666* | 2.04167 | 0.05246111* | 55.6753425* |
| Drip lateral spacing × Mulching | 3 | 4347333.2 | 0.00446667 | 5849658.8 | 10.5928 | 2.375 | 0.02324 | 3.00633 |

DF = Degree freedom, WUE = water use efficiency, HI = harvest index, * = significantly different.

under plastic mulch. So, the moisture content of soil under plastic mulch becomes lower in the long term. Plastic mulching prevents the leaching of fertilizer, because it acts as a physical barrier to irrigation water and/or rainfall and prevent leaching of nutrients. Plastic mulch reduces the splattering of soil on onion leaves during rains or sprinkling. This can reduce losses due to soil-borne diseases (Steiner et al., 1998; Derpsch, 2001; Westerfield, 2013). Similarly, Hamma (2013) reported that the highest bulb yield was observed from white plastic mulch than no mulch and other treatments. Anusuya and Betsy (2001) found that vegetable yields were significantly higher, heads larger, and harvest earlier for plants grown under white plastic mulch compared to the control and other mulch treatments. Allen et al. (1998) reported that mulching with polyethylene did significantly improve bulb yield of onion than straw mulch. But Allen et al. (1998) indicated that no yield advantage was observed using white as against black plastic mulch. From field observation of this experiment, almost no onion flower was observed from onion grown under white plastic mulch and the growth of above ground plant parts was shorter in height. Onion grown under white plastic mulch was matured earlier than others. But onion grown under wheat straw mulch, black plastic mulch and no mulch were almost all flowered. The effect of flower was reduced bulb yield. The observation indicates that white plastic mulch conserved moisture and is transparent thereby allowing the penetration of light through it which enhanced the photosynthetic activities of plants resulting in the production of higher treatment means than the rest of the treatments. Field observations during the trials indicated that there is high weed germination under wheat straw mulch treatment resulting in high labor consumption for weeding operation, relatively high moisture competition and crop-damage as a result of soil disturbance during hand weeding. These contribute to lower mean bulb yield. In the control treatment, there was no moisture conservation in which the plants under this treatment were denied adequate moisture for normal growth and developmental processes due to excessive evaporation thus resulting in the production of lower treatment means as earlier reported by Baten et al. (1995) and Duranti and Cuocolo (1989). It is observed that weed germination under no mulch was almost less than that of wheat straw mulch due to moisture stress.

### Interaction effects of different drip lateral spacing and mulch types on onion yield and water use efficiency

The summarized mean values of onion yield and water use efficiency showed that there were non-significant ($P \leq 0.05$) difference due interaction effects of lateral spacing and mulch types. (Table 3)

### Economic analysis and evaluation

Based on drip lateral spacing, the cost of treatment in which the drip lateral between two onion plant rows was 50.34% less than the treatment in the drip lateral in every onion plant rows (Table 4). Even though the total variable cost of implementing drip lateral in every row was greater than that of drip laterals between two rows, drip lateral in every row gave the maximum net income of 246,410 ETB ha$^{-1}$. On the other hand, less net income of 238,070 ETB ha$^{-1}$ was obtained from drip lateral between two rows. This means farmers installing drip laterals in between two onion plant rows for production of onion under drip irrigation losses 8,340 ETB ha$^{-1}$ under Ambo climate condition. Similarly, Himanshu et al. (2012) reported that drip lateral in every row resulted in higher gross return, net return and benefit cost ratio.

The mean values of marginal rate of return (MRR) revealed that no mulching gave the higher value than the control treatment (no mulch). Thus, the highest net benefit of 284,616 ETB ha$^{-1}$ was recorded from no mulch and followed by 280,329

**Table 4.** Effect of drip lateral spacing and mulching on net benefit of onion production at Ambo.

| Treatment | Mean bulb yield (kg ha$^{-1}$) | Adjusted bulb yield (kg ha$^{-1}$) | Gross field benefit (ETB ha$^{-1}$) | TVC (ETB ha$^{-1}$) | Net benefit (ETB ha$^{-1}$) | Value to cost ratio | MRR (%) |
|---|---|---|---|---|---|---|---|
| Drip lateral between two rows | 30230 | 27207 | 272070 | 34000 | 238070 | 7 | - |
| Drip lateral in every row | 34990 | 31491 | 314910 | 68500 | 246410 | 3.6 | 24.17 |
| No mulch | 31795 | 28615.5 | 286155 | 1539.35 | 284616 | 184.89 | |
| Wheat straw mulch | 32498 | 29248.2 | 292482 | 12152.8 | 280329 | 23.07 | -0.4 |
| White plastic mulch | 35117 | 31605.3 | 316053 | 45037 | 271016 | 6.02 | -0.28 |
| Black plastic mulch | 32030 | 28827 | 288270 | 48796.3 | 239474 | 4.96 | -8.39 |

TVC = Total variable cost and ETB = Ethiopian Birr, MRR = marginal ret of return. The price of onion = 10 ETB kg$^{-1}$.

ETB ha$^{-1}$ was recorded from no mulch and followed by 280,329 ETB ha$^{-1}$ with wheat straw mulch for onion production (Table 4). The lowest net benefit 239,474 ETB ha$^{-1}$ was obtained from black plastic mulch. The value to cost ratio for no mulch was 184.89 and that of black plastic mulch is 4.91. This result confirms the farmer's production practices (drip lateral in every row and no mulch) are economically feasible for onion production in sub humid areas of Ambo.

## Conclusion

The results of this experiment indicated that interaction effect of drip lateral spacing and mulching on onion yield and water use efficiency showed non-significant difference ($P \leq 0.05$). But the main effects of both drip laterals spacing and mulching showed significant difference ($P \leq 0.05$) on bulb yield, water use efficiency, plant height, bulb diameter and harvest Index. On the other side the mean value of biomass and plant population showed non-significant ($p \leq 0.05$) difference due to main effect of drip lateral spacing and mulching. The highest bulb yields of 34990 and 35177 kg ha$^{-1}$ were recorded from drip lateral spaced in every row and white plastic mulching, respectively. The highest irrigation water use efficiency was 1.14 kg L$^{-1}$ recorded from drip lateral in every row and 1.15 kg L$^{-1}$ from white plastic mulching. Even though white plastic mulch yields more, the economic analysis result showed that no economic advantage was obtained by the use of wheat straw, white and black plastic mulches when compared with that of control (no mulch) for drip irrigated fresh marketable bulb yield of onion at Ambo. Drip irrigation method is also profitable for onion production with drip lateral spacing in every row with net benefit of 24640 ETB ha$^{-1}$ and its marginal net of return is 24.17%.

It was observed that reducing drip laterals from one drip lateral for each onion plant row to one drip lateral for two onion plant row caused significant yield reduction which resulted in reduced net benefit in the study area. The use of white plastic mulch, black plastic mulch and wheat straw mulch for the production of drip irrigated onion have no net benefit than producing onion without mulching around Ambo.

Drip lateral spacing in every row and no mulch mulching is profitable for smallholder farmers' by providing different biological and economic advantages that enhance sustainable onion production.

## COMPETING INTERESTS

The authors declare that they have no competing interests.

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# Impacts of human resettlement on forests of Ethiopia: The case of Chamen-Didhessa Forest in Chewaka district, Ethiopia

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**Ethiopia has been practicing population resettlement programmes since 1960s mainly as a response to extreme land degradation in the highlands. The programmes were carried out mainly in the lowlands of western, southwestern and southern Ethiopia. Accordingly, 12,305 households (56,715 people) from Eastern and Western Hararghe zones were formally resettled in Chamen-Didhessa forest in Chewaka district. The major aim of this study was to assess the impacts of resettlement on the forest cover between 2004 and 2016. Data about the size of farmland held by the respondents and other issues related to the forest were randomly collected from 360 households from four sites through semi-structured questionnaires. Data were analyzed using descriptive statistics. Of the 54,200 ha of the natural forest, 38,906 ha (72%) was cleared by the government during the preparation for the resettlement programme in 2004. About 58% of the remaining forest land was deforested by the resettlers between 2004 and 2016. The average of farmland possessed by each household was 1.74 ha at the beginning of settlement in 2004 and it increased to 2.1 ha in 2016. The major causes for the forest cover reduction after the settlement were clearing of forest for farmland expansion, forest burning, cutting of trees for firewood, charcoal production and construction wood and logging. The human population increased from 12,305 households (56,715 people) in 2004 to 19,415 households (71,809 people) in 2016. The government has to take measure to rehabilitate the forest and conserve the remaining one.**

**Key words:** Chewaka district, deforestation, forest, forest resource, population pressure, resettlement.

## INTRODUCTION

Resettlement refers to a planned or spontaneous phenomenon of population relocation (Dessalegn, 2003). Resettlement can be implemented either voluntary or forced. When people resettle in a new place under their own initiative, this may be called 'spontaneous resettlement'. If the resettlement is imposed on people

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by an external agent in a planned and controlled manner, it may be called ‘planned resettlement’ (Gebre, 2002). Planned resettlement seems to be the more appropriate to the Ethiopian context, as it suggests the deliberate moving of people to areas other than their own localities, that is, from places of origin to other locations (Dessalegn, 2003).

Ethiopia has been practicing population resettlement going back to the 1960s under the imperial regime (1930-1974) when, through a combination of spontaneous and planned settlement programmes, a relatively small number of northern peasants were settled in western Ethiopia and the Rift Valley areas (Dessalegn, 2003). The resettlements have been carried out mainly as a response to extreme land degradation and recurrent drought-induced famine (Messay, 2009). The resettlement schemes, past and present, are implemented by settling them predominantly in the lowlands where population densities are low and unutilized but potentially productive and risk free lands. The recent government sponsored resettlement schemes are more planned than the cases of the previous governments (Messay, 2009; Shumete, 2013).

The Imperial Government established the first known planned resettlement scheme in the present day Southern Nations and Nationalities Peoples National State (Cernea, 2000) which involved only 20,000 households (Feleke, 2004). It was during the Military Government (*Derg*) (1974-1991) that intensive and widespread resettlement schemes took place in Ethiopian history. *Derg* argued that the major objective of the program was to promote economic development and improve the living standards of the rural people. Specifically it aimed to ease the tension of farmland scarcity in central and northern parts of the country, combat drought, avert famine, and increase agricultural productivity. However, practically the implementation of the program seemed to have the characteristics of forced or compulsory-voluntary relocation. *Derg* implemented it forcefully and even on quota bases without the consent of the potential resettles (Ofcansky and LaVerle, 2002). The regime resettled many thousands of households at different times mainly from the north, notably Wello, Tigray and Shewa to the lowland areas of western and southern parts of the country, especially Wellega, Kafa, Illu Aba Bora and Gojjam, Gambela, Pawe (in the present day Benishangul-Gumuz National Regional State) and West Gonder (Gebre, 2002; Berhanui, 2007; MoARD, 2009).

The current Ethiopian government in power, Ethiopian Peoples Revolutionary Democratic Front (EPRDF) has also continued the resettlement program whose objective of the scheme remains similar to that of the military regime that is, ensuring food security. Accordingly, 45,000 households were resettled voluntarily in Amhara, Oromia and Tigray regions in the year 2002/2003 alone (Berhanu, 2007). The current resettlement by the EPRDF Government states that the program is based on voluntary approach. According to the Voluntary Resettlement Programme, each settler household is supposed to be allocated a package of assistance that includes access rights to up to 2 ha of fertile land, seed, oxen, hand tools, utensils, and food rations for the first eight months.

The expansion of agricultural land in the country in general, could be directly related to rapid population growth and resettlement programs (Solomon, 2016). The thinking behind resettlement schemes can be understood in terms of both social protection and agricultural policy goals. Facilitating the relocation of farming families from areas where land is constrained, agricultural productivity is low and agricultural risk is high, to areas where land is more abundant, agricultural productivity is potentially higher and agricultural risk is lower, seems like an effective strategy for reducing vulnerability (a core social protection objective) and raising yields (a core agricultural policy objective). While this sounds like a ‘win-win’ outcome in theory, in practice resettlement schemes in Africa have more often failed than succeeded, mainly because they are implemented too quickly with inadequate preparation (e.g. providing basic infrastructure and services at the relocation sites, and ensuring that ‘open’ land is not actually dry season grazing for pastoralists) (Stephen and Bruce, 2007).

Forest cover in some parts of southwest Ethiopia has decreased from 71 to 48% between the years of 1973 and 2005 (Wakjira and Tadesse, 2007). The larger portions of the existing forest are even secondary (planted by man) due to widespread human influence (Kidane, 2002).

The ever-increasing human population coupled with unwise land use and farming systems, unsustainable forms of agricultural intensification, and catchment degradation has resulted in serious degradation of these important forest resources. These coupled with the impacts of climate change leads to economic destabilization and habitat destruction and loss.

Assisted by the government, 12,305 households (56,715 people) from Eastern Hararghe zone and Western Hararghe zone were formally resettled by the government in Chamen-Didhessa forest (54,200 ha) at seven sites in Chewaka district of Buno Bedele zone (formerly part of Ilu Aba Bora zone) of Oromia National State in 2004. The settlers were selected from highly degraded areas where agricultural production was poor and hence experienced chronic food insecurity (COWARDO, 2015). Each household was provided with farmland that ranged between 1 and 2.5 ha (Berhanu, 2007). The people were resettled in dense forest that was not inhabited by people before the resettlement programme and thus the land was under state holding system.

Therefore, the aim of this study was to assess the impacts of state assisted resettlement program on deforestation of Chamen-Didhessa forest of Chewaka

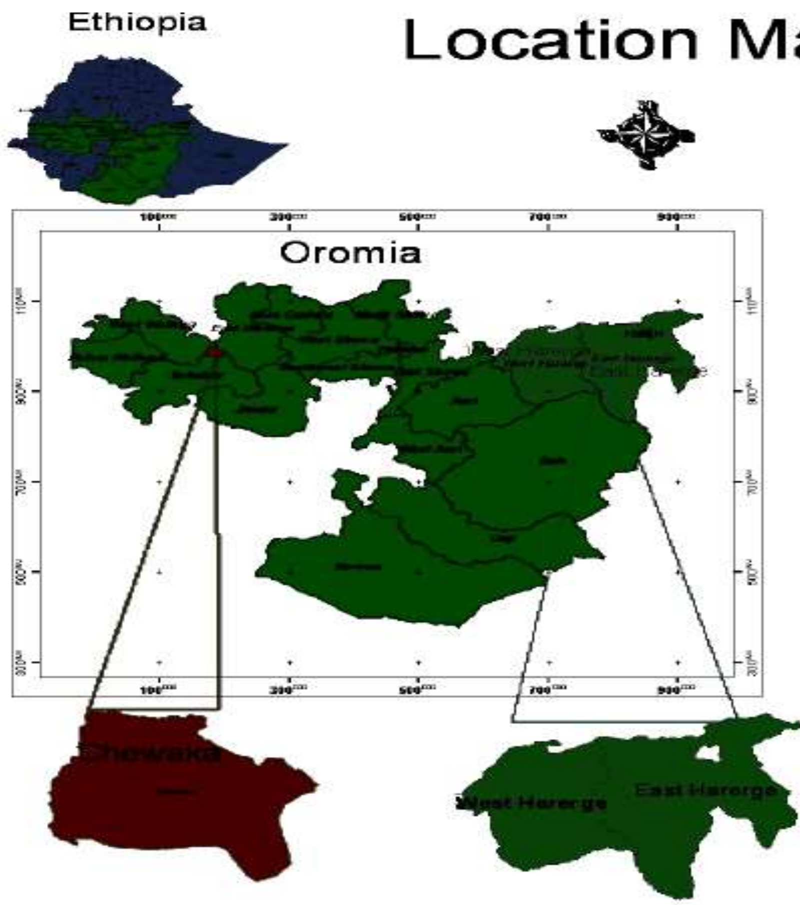


**Figure 1.** Location map of Chewaka Resettlement Scheme.
Source: Masresha and Ignatius (2013).

district.

## MATERIALS AND METHODS

### Description of the study area

Chewaka district (Figure 1) was established in 2004 through formal settling of 12,305 households (56,750 people) brought from Eastern and Western Hararge zones by the government. About 38,906 ha of forest land was cleared by the government to resettle the people (COWARDO, 2015). The forest was a home for wild animals such as lion (*Panthera leo*), leopard (*Panthera pandus*), hyena (*Crocuta crocuta*), African buffaloes (*Syncerus caffer*), bushbuck (*Tragelaphus scriptus*), common baboon (*Papio cynocephalus*), warthog (*Phacochoerus africanus*), bush pig (*Potamochoerus larvatus*), python (*Python sebae*), porcupine (*Hystrix cristata*), colobus monkey (*Colobus guereza*, common duiker (*Sylvicapra grimmia*), Vervet monkey (*Cercopithecus aethops*) among others. Likewise Dhidhessa River which crosses the area is habitat for crocodile (*Crocodylus niloticus*) and hippopotamus (*Hippopotamus amphibius*) (Berhanu, 2007).

Chamen-Didhessa forest is found in Chewaka district, Buno Bedele Zone of Oromia National State. The district is found at about 420 km west of Addis Ababa, covering an area of about 542 km$^2$. It is located between 13°40' and 14°27'W and 36°27' and 37°32'S. The elevation ranges from 900 to 1400 m above sea level. The annual average temperature is 24°C. Annual average rainfall of the district ranges from 1,200 to 1,500 mm. The district is bordered by four districts: at north by Diga (Arjo Gudetu), at south by Dabo Hana, at east by Jimma Arjo, and by Meko at west (CWARDO, 2015).

The major crops cultivated in the area are maize, rice, and sorghum for consumption, while crops like sesame, soybean, khat and coffee are grown mainly as cash crops. Cattle and goats are the major livestock reared in the area. The livestock production systems of the settlers differs from that of the nearby indigenous community in that the former raise less livestock and fatten them for sale (CWARDO, 2015).

### Sample size determination and methods of data collection

Data were collected through semi-structured questionnaires with 360 household sample settlers selected by simple random sampling method. Four sites (sites 1, 5, 6 and 7) were purposively selected of the total seven sites of the settlement area based on their accessibility. In total the number of households of the four sites was 6434 (site one with 1684, site five with 1548, site six with 1800, and site seven with 1402 households). Therefore, total sample size required for the study and the sample size of each site were determined by the following formula at 95% degree of confidence, for population less than 10,000 (Sudman, 1976).

**Table 1.** Percentage of resettlers in Chamen-Didhessa forest by year and types of resettlement.

| Time of settlement (year) | Percentage (number) |
|---|---|
| In 2004 | 78.33 (282) |
| After 2004 | 21.67 (78) |
| Total | 100 (360) |
| **Type of settlement** | |
| Formal | 78.33 (282) |
| Informal | 21.67 (78) |
| Total | 100 (360) |

$n = N/1 + N(e)^2$

where n = total samples included in the study, N = total number of households of selected sites (6434), e = desired level of precision (0.05).

$n = 6434/1 + 6434(0.05)^2 = 360$ were selected as total sample size

Sample size for each site ($n_i$) was determined as:

$n_i = N_i n/N$

where n = total calculated sample, $n_i$ = sample size of each selected site, N = total households in all selected sites, and $N_i$ = households of each selected site.

Therefore,

No. of site one = (1684 × 360)/6434 = 94
No. of site five = (1548 × 360)/6434 = 87
No. of site six = (1800 × 360)/6434 = 101
No. of site seven = (1402 × 360)/6434 = 78

The questionnaire administered to the sample settlers was first prepared in English and then translated into the local Afan Oromo language. As majority of the respondents were unable to read and write, the questionnaire was read for each respondent individually by trained field assistants and their responses are written. Data about the size of the forest prior of clearing it for the preparation of the resettlement and the size of the forest land cleared for the resettlement was collected through an interview made with the manager of the Agricultural and Rural Development Office of Chewaka district and secondary data from CWARDO (2015).

### Data analyses

Collected data were analyzed using descriptive statistics (percentage, frequency and mean) with Microsoft excel.

## RESULTS AND DISCUSSION

### Population of settlers and forest size at the beginning of resettlement

As per interview made with the manager of Chewaka District Agricultural and Rural Development Office (CDARDO), Chewaka district was established for the resettlement purpose by clearing the existing natural forest. The total area of the district is 542 km$^2$ (54,200 ha) which was totally covered with forest prior to the 2004 resettlement program. In 2003/2004 about 38,906 ha of the forest was aggressively destroyed by the government for the resettlement programme (CWARDO, 2015) and this shows that only 15,294 ha of forest remained at the time of the resettlement. This shows that about 72% of the forest was cleared by the government at the time of preparing the land for the resettlement purpose.

According to the manager of CDARDO, 12,305 households (56,715 people) were resettled formally in 2004 after which no planned resettlement was carried out. The same source also indicates that 7,110 households settled informally after 2004 and the total number of settlers increased to 19,415 households (71,809 people) in 2016. About 78% (n = 282) of respondents mentioned that they were formally settled by the government at the beginning of the resettlement while 22% of them settled later informally (Table 1).

The respondents argued that after the formal resettlement programme of the 2004, informal settlement continued in the forest both from the existing formal settlers themselves (children of the settlers when became independent of their parents) and other people coming from different areas outside the settlement area which contributed for the population increase in the forest. The reasons for the resettlement were mainly to acquire farmland for crop cultivation and forest resource extraction and these were the major causes of deforestation practiced without any control by the local government. In a similar study, Messay (2009) reported that alarming increase in population size following the 2003 and 2004 resettlement program in Jiru Gamachu in Central Ethiopia, the dense grasslands and woodland vegetation have been entirely converted to villages, grazing and farming lands. Messay and Bekure (2011) also noted that in Nono Resettlement sites in Central Ethiopia, the existing high rate of population growth and the resultant newly emerging households seems exerting another immense pressure on land resources in the area. The emerging young households need cultivable land for livelihood purposes. This, undoubtedly, intensifies the conversion and/or modification processes of the land use types. They may be forced to encroach into vegetated lands for cropping, grazing, and settlement. Solomon (2016) noted that forest degradation in Ethiopia is closely linked to the ongoing population growth. More people generally lead to an increasing demand on land for living and for agricultural production. Consequently the pressure on the forest resources themselves increased due to a higher demand on fuel wood and construction timber.

Deforestation and degradation of habitats due to the action of settlers are among the major contributors to current global climate changes and biodiversity losses (Foley et al., 2005). Temperature changes due to

**Table 2.** Percent frequency (number) of participants' land size possession in 2004 and in 2016 (n = 360).

| Land size (ha) | 2004 | | 2016 | |
|---|---|---|---|---|
| | Percent (frequency) | Total land size (ha) | Percent (frequency) | Total land size (ha) |
| 0 | 10.56 (38) | - | - | |
| 1 | 5.28 (19) | 19 | 20.28 (73) | - |
| 2 | 84.16 (303) | 606 | 57.50 (207) | - |
| 3 | - | - | 17.50 (63) | - |
| 4 | - | - | 3.89 (14) | - |
| ≥5 | - | - | 0.83 (3) | - |
| Total | 100 (360) | 625 | 100 (360) | 747 |
| Mean | 1.74 | | 2.1 | |

deforestation and burning forest lead to altered distribution of vector borne diseases (Magadza, 1995). Human settlements change the well stand of the forest, changes species composition observed in the locality are largely due to transition vegetation types influenced by extraction of green foliage, fire wood, timber and forest products for domestic use by inhabitants of the area. Settlements in the forest reduce the area of the forest, as settlers have no better sources of income, they have no other better alternative of fuel resources than extracting fuel wood from the nearby forest.

## Farmland expansion and forest cover change

Besides the impacts of newly incoming informal settlers on the forest, the former formal settlers acquired additional farmlands than they were provided by the government. The size of land owned by settlers at the time of resettlement in 2004 and in 2016 is shown in Table 2. The results of this study revealed that the maximum size of farmland possessed by a household was 2 ha and the average was 1.74 ha at the beginning of the resettlement in 2004. In 2016, the maximum size of land was 5 ha and the average was 2.1 ha. The mean difference was 0.34 ha and this is an equivalent forest land size cleared by each settler within 12 years. Therefore, about 6601 ha of forest land was converted to farmland by the current 19,415 household settlers and the forest reduction rate was 550.1 ha per year. After the implementation of the resettlement program, the forest cover was amazingly declined from 15,294 to 8711 ha between 2004 and 2016 and only about 16% of the forest's spatial coverage remained after 12 years. The findings of this study, thus, indicated that resettlement was one of the major causes for the depletion of natural forests of the district. This result was also in agreement with the interview made with the manager of the district's Agricultural and Rural Development Office who mentioned that though the current forest land cover is not exactly known, it does not exceed 9,000 ha and this remaining forest is under threat.

Different forests in parts of the country also face similar threats where resettlements were implemented. In Amhara National Regional State, Ethiopia, Teshome et al. (2011) reported that in Metema Woreda woodland coverage that was 232,001 ha (72.8%) before the resettlement of 2003 increased to 201,906 ha after the resettlement while that of Quara Woreda declined from 535,537 to 493,969 ha after the resettlement program.

## Impacts of fire on forest

All the respondents agreed that the size of the forest had been declining alarmingly from time to time. Ninety-eight percent (n = 354) of the respondents agreed that the settlers severely affected the forest. They mentioned the underlying causes of deforestation and degradation as clearing and burning of forest (for further farmland expansion and new settlement, hunting wild animals, protecting domestic animals and themselves from some wild animals which attack them), harvesting firewood, charcoal production, and construction wood harvesting. Burning of forest was also evidenced from field observation.

When the settlers used fire for such purposes, sometimes fire went of control and often caused accidents of economic significance (Table 3). All the respondents mentioned that they used fire for preparing their farmlands and only about 11% (41) of them used fire control methods (for a possibility that the fires might go out of control) such as clearing grasses on the farm boundary and around houses.

The need for cultivation and grazing lands, settlements, charcoal production, commercial wood and construction materials have contributed much to the reduction of the forest cover in Ethiopia. In this way, the misutilization of wood production by rural human communities aggravates the degradation and habitat loss of wildlife. Habitat losses and fragmentation caused by human impacts is the greatest threat to the majority of Ethiopia's wildlife

**Table 3.** The impacts of fire accidents on the livelihood of resettlers in Chamen-Didhessa forest.

| Year | Fire accidents | Sites |
|---|---|---|
| 2012 | Sire Gudo First Cycle School, teachers' shelter and properties and settlers' houses were burnt | 4 |
| 2013 | 10 ha of maize and sorghum in the field and settlers houses were burnt | 6 |
| 2014 | Settlers houses were burnt and accident to family members of one household | 4 |
| 2015 | Settlers houses were burnt | 5, 6 |
| | Bechege Satellite School was burnt | 1 |
| 2016 | Oda Kebena Satellite School was burnt | |
| | Settlers houses were burnt | 1, 5, 6 |

Source: Interviews with respective site manager of the settlement area.

species (Giller et al., 2001). Whatsoever type it is, most planned resettlement schemes in the world, including that of Ethiopia, has been reported to be unsuccessful and environmentally devastating (Messay and Bekure, 2011).

Dessalegn (2003) reported that government sponsored large-scale resettlement programs that were carried out in the lowlands of western, southwestern and southern Ethiopia during 1984/1985 involved considerable environmental damage by clearing large areas of vegetation to build homesteads, to acquire farmland, and to construct access roads. He also indicated that the scheme failed to adapt farming practices to agro-ecological conditions of the lowlands, and as a consequence the environmental damage involved was quite considerable.

Rowe et al. (1992) stated that people use trees and other tree products for house building, energy sources, due to such needs directly and indirectly affect the forest or plant diversity and also affected by agriculture expansion through cutting for shifting to farmland. All the respondents (100%) mentioned that the main source of firewood and the only source of construction wood was the natural forest and 57% (n = 206) of the respondents used crop residue as source of firewood in addition to natural forest. These combined with clearing and burning of forest inevitably result into forest degradation. The major indigenous trees which the settlers usually used for house construction and source of energy are shown in Table 4.

## Impacts of settlement on wild animals

Forest ecosystems contain a large number of biodiversity and when these are cultivated and crops are planted, the huge biodiversity is lost and replaced by few crops and weeds. Animal distribution, biodiversity and density depend on that of plants. Destruction of forest ecosystem threatens animal and plants of the forest and eventually will lead to local extinction of the species. Ukizintambara (2008) stated that habitat loss and fragmentation by human activities affect the survival of wildlife species in various ways including influencing animal behaviors, reducing of the total amount of usable habitats, degrading habitat quality and creating edge effects. Small population size increases vulnerability of wildlife to extinction especially when human distributions increase. Besides deforestation the resettlement program was also responsible for the killings and fleeing of wild animals. When farmers destroy forests which are habitats of wild animals for the sake of expansion of farmlands and enhancing of grass growth for the livestock, population of wild animals will be affected because of migration and death caused by shortage of food and lack of habitat. All the respondents mentioned that the forest was a home of buffaloes, warthogs, antelopes, baboons, lions, wild pigs, leopards, and hyenas at the beginning of the resettlement. The forest was particularly known for its high buffalo population before the settlement. About 99% (n = 356) of the respondents agreed to the existence of human-wild animals conflict in the area and larger wild animals were highly affected by the conflict. Most of the respondents (91%) agreed that the conflict had been increasing from time to time because of human population increase and alarmingly declining forest cover, illegal hunting and killing of aggressive animals which attack both humans and livestock and damage crops. All the respondents mentioned that they had experience of hunting wild animals for different purposes (Table 5). Due to anthropogenic activities after the settlement, the existence of buffaloes was highly threatened and their habit and behavior was changed and most of them migrated to the nearby Meko forest. The remaining buffalo population became more aggressive and caused severe damage to crops and attacked humans on the farm and in the forest.

## Forest conservation and rehabilitation

Resource conservation and rehabilitation in Ethiopia in general is very limited as compared to its loss and degradation (Berhanu, 2007). The removal of trees without sufficient reforestation has resulted in damage to

**Table 4.** Major indigenous trees cut by the resettlers from Chamen-Didhessa forest of Chewaka district.

| Plants' scientific name | Local name (Afan Oromo) | Purpose |
|---|---|---|
| *Cordia africana* | Waddeesa | Timber (logging), farm utensil, firewood and house construction |
| *Ficus wasta* | Qilxuu | House construction, firewood and charcoal preparation |
| *Syzygium guinense* | Goosuu | House construction, firewood and charcoal preparation |
| *Podocarpus falcatus* | Birbirsa | House construction and firewood |
| *Acacia spp.* | Laaftoo | House construction, firewood and charcoal preparation |
| *Erythrina abysinica* | Waleensuu | House construction and firewood |

**Table 5.** Respondents' views towards reasons for hunting wild animals in Chamen-Didhessa forest of Chewaka district (n = 360).

| Purpose of hunting wild animals | Percent (number) |
|---|---|
| Food (flesh) | 33.33 (120) |
| Skin (hides) | 13.33 (48) |
| Culture | 1.67 (6) |
| Protecting properties and self defence | 51.67(186) |

habitat, biodiversity loss and aridity and deforested regions often degrade into wasteland (Tigabu, 2016). Most of the respondents (96%) mentioned that no measure was taken by the settlers to conserve the forest and other resources in the forest. The rest of the respondents (4%) mentioned that measure was taken by the society like by advising those people who cut and burn the forest. About 74% (n = 266) of the respondents agreed that the government did not take any measure to mitigate forest damage related to settlement, while 26% (n = 94) mentioned that some measures had been taken by the government such as advising people to stop cutting trees, planting tree seedlings when cutting trees for replacement, though these measures were loose and inconsistent and thus brought no measurable results which calls for appropriate awareness creation.

Wise use of forest resources is crucial for sustainability of the forest and trees should be replaced by planting seedlings. However, most (91%) of the respondents mentioned that they did not engage in tree planting on their farmlands and homesteads which could substitute the wood products from the natural forest and the rest of the respondents (9%) the planted only mango trees. Similarly, Teshome et al. (2011) reported that in the resettlement areas of Metema and Quara districts, in general, natural resource degradation was moving at an alarming rate, resettlers' total level of participation in natural forest protection and tree planting was found to be at low level because of lack of awareness. They also reported that 95.8% of respondents in Metema and 92.3% in Quara never engaged on private land conservation practices after the resettlement program. Similarly, 53.5 and 52.1% in Metema and Quara, respectively never participated on communal land conservation practices in their new resettlement areas.

## Conclusion

The results of this study revealed that the resettlement resulted in severe deforestation of Chamen-Didhessa forest. Of the 54,200 ha of the forest, 38,906 ha (72%) was cleared by the government during the preparation for the resettlement programme in 2004. The remaining 15,294 ha of the forest cover was declined to 8711.1 ha in 2016 within 12 years. The major causes for forest cover reduction after the settlement were clearing of forest for expansion of farmlands, forest burning, population growth and immigration of people settling informally in the forest, cutting of trees for firewood, charcoal production and logging. The existing high rate of population growth and the resultant newly emerging households seems exerting another immense pressure on the forest cover. The human population in the settlement area increased from 12,305 households (56,715 people) in 2004 to 19,415 households (71,809 people) in 2016 thus it had its contribution for the deforestation. The wild animals in the settlement area were also affected due to lack of sufficient food and habitat because of deforestation and killing by the settlers for different reasons. Unless appropriate environmental protection and rehabilitation measures are taken soon, the remaining forest will be entirely deforested within very short period of time and the problem will expand to the dense forests of the neighboring districts of Dabo, Meko, and Jimma Arjo. Hence, it is imperative to take all the necessary measures by the local government offices, NGOs, and other concerned bodies to rehabilitate the deforested environment and conserve the remaining forest.

## Recommendations

Depending on the results of this study the following points were put forward as recommendation.

(1) Awareness raising activities should be conducted about conservation of forests, wildlife, and proper utilization of other national resources in a sustainable and environmentally friendly manner.
(2) The government should not resettle people in forests for future possible resettlements.
(3) The responsible governmental bodies should control any further informal settlement to reduce the pressures exerted on the forest by increased population.
(4) Encouraging the community to implement agroforestry practices by planting trees in the farm and homesteads.
(5) Promoting planting and use of trees like Eucalyptus as alternative for firewood and construction material.
(6) The local government should control the sale of wood and charcoal in the forest area, on road and local markets.
(7) Assisting farmers by giving them agricultural inputs and new farming technics to enhance high crop yield from a small plot of land.
(8) Reforestation activities should be launched in deforested and degraded areas by actively involving the settlers.
(9) The resettlement schemes in Ethiopia lacked environmental considerations. Therefore, the outcomes of this study could be used as an important indicator for decision makers to make environmental impact assessment for possible future resettlement programs.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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