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Editor's Note

This issue of the *Ethiopian Journal of Business and Development* features interdisciplinary research addressing key development issues in Ethiopia, including agricultural productivity, digital financial inclusion, ICT use in private higher education, data-driven approaches in geotechnical engineering, and factors influencing recidivism in correctional institutions. The articles provide evidence-based insights relevant to researchers, practitioners, and policymakers. We thank the authors and reviewers for their valuable contributions.

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Effect of Varieties and Planting Dates of Bread Wheat-lupine Intercropping System under Additive Design in Northwest Ethiopia

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Abstract

Food production, on ever-dwindling agricultural land, is a severe problem in Ethiopia, necessitating the adoption of more efficient and sustainable land-use strategies to feed the country's growing population. The benefits of intercropping are known to be limited by a variety of factors, such as companion crop sowing date and variety. The present study was, therefore, initiated to evaluate the effect of varieties and planting dates of lupines in bread wheat-lupine under an additive design intercropping system in Northwest Ethiopia. Field experiments were conducted for two years in Adet and Debre Tabor experimental sites. The treatments consisted of four planting dates of lupines and two varieties of lupines. Moreover, the sole crop of bread wheat (Triticum aestivum L.), local lupine (Lupinusalbus L.), and sweet lupine (Lupinusangustifolius L.) were also included. The experiments were laid out in a factorial randomized complete block design (RCBD) with three replications. The results showed that at the Adet experimental site, the highest land equivalent ratio (LER) was recorded in the simultaneous planting of sweet lupine and bread wheat (1.3), followed by the planting of sweet lupine two weeks after bread wheat (1.23). At the Debre Tabor experimental site, the highest LER was recorded in planting sweet lupine two weeks after bread wheat (1.67). A greater area time equivalent ratio (ATER) was reported in the simultaneous planting of sweet lupine and bread wheat (1.29), followed by the planting of sweet lupine after bread wheat (1.22) at the Adet experimental site. A greater ATER was also recorded in the planting of sweet lupine after bread wheat (1.53), followed by simultaneous planting (1.39) at the Debre Tabor site. This revealed that sole cropping would necessitate 29% and 53% more area, respectively, to attain the same yield as intercropping. In Adet, the simultaneous planting of sweet lupine and bread wheat boosted productivity and production efficiency, while in Debre Tabor, planting sweet lupine two weeks after bread wheat proved to be a viable option for increasing household food security.

Keywords: Additive design, intercropping, land equivalent ratio, planting dates, production efficiency

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1. Introduction

Developing countries like Ethiopia are particularly affected by climate change due to their agrarian economies, which are heavily dependent on natural resources (Emerta, 2013). Agriculture is closely tied to weather and climate, both of which are key factors influencing output (Roudier *et al.* 2011). Climate change impacts crop yield and quality (Southworth *et al.* 2000), necessitating the selection of appropriate adaptation strategies (Singh *et al.* 2014; Yin, 2013; Haverkort and Verhagen, 2008) to mitigate negative effects while maximizing potential benefits to meet the demands of a rapidly growing global population (Wart *et al.* 2013; Daccache *et al.* 2011). As a result, there has been an increase in land-use intensification and agricultural diversification (Alene *et al.,* 2006). Among sustainable farming methods, intercropping, particularly the planting of cereals with legumes, offers an excellent solution to these challenges (Agegnehu *et al.* 2006).

Panda (2010) defines intercropping as the simultaneous cultivation of two or more crop species on the same land, where they share resources during all or part of their growing season. This practice is increasingly recognized as a vital component of long-term agricultural development, promoting crop diversity within farming systems (Jensen *et al.* 2015; Laurent *et al.* 2015). As agricultural land becomes scarcer, the significance and intensity of intercropping grow (Niguse and Reddy, 1996). Intercropping is commonly used in tropical regions, where farming often operates with limited inputs (Laurent *et al.,* 2015). It is known to increase farm productivity, reduce labor peaks, minimize crop failure risks, and maximize net income (Bitew *et al.* 2019).

In Ethiopia, intercropping is prevalent, typically involving both cereals and legumes. Cereals are the primary food source, with their output far exceeding that of legumes (Willey, 1979). Wheat, in particular, is the most important crop, providing the majority of the country's caloric intake. Lupines are also used as a versatile crop in the region (Yeheyis *et al.* 2012). Subsistence farmers often use lupines as supplementary crops in areas with poor soil fertility (Bantie *et al.* 2014; Yeheyis *et al.* 2012).

However, the benefits of intercropping can be limited by factors such as the timing of component crop sowing, crop variety, and crop selection, all of which can also impact overall productivity (Pal *et al.* 1988). In intercropping systems, selecting the right crop combination, determining the optimal planting date, and employing a planting pattern that minimizes competition while enhancing facilitation between component crops are critical (Bantie *et al.* 2014; Lithourgidis *et al.* 2011; Munnu, 2003). Depending on the farmer's objectives and the value of the crops, an additive design

(keeping the density of one species constant while varying the density of another) may be used to combine species in intercropping systems (Connolly *et al.* 2001). Farmers in northwest Ethiopia apply simple, natural principles to manage bread wheat-lupine intercropping under an additive design, aiming to maximize complementarity and minimize competition. However, no systematic research has been conducted to select compatible lupine varieties with bread wheat under this system, particularly with the correct planting dates, to optimize the intercropping system using various sole crop production scenarios. Therefore, the objective of this study was to evaluate how different lupine varieties and planting dates might affect the production of bread wheat-lupine intercropping under an additive design in Northwest Ethiopia.

2. Research Methods and Materials

2.1. Descriptions of the Study Sites

A field experiment was conducted during the rainy seasons of 2019 and 2020 in two key wheat-producing districts in northwest Ethiopia: Adet and Debre Tabor. Adet is located at a latitude of 11°16’N and a longitude of 37°29’E, with an altitude of 2,240 meters above sea level (Adet Agricultural Research Center, 2011). Debre Tabor is situated at a latitude of 11°51’N and a longitude of 38°1’E, with an elevation of 2,630 meters above sea level. According to the Bahir Dar Meteorology Station (2020), the Adet district received a total rainfall of 1,592.1 mm and 1,228.1 mm during the 2019 and 2020 cropping seasons, respectively (Figure 1). The Debre Tabor district received 1,926.1 mm and 1,739 mm of rainfall in 2019 and 2020, respectively (Figure 2). The minimum and maximum temperatures at Adet were 5.4°C and 30.2°C in the 2019 season, and 6.8°C and 30.7°C in the 2020 season. In Debre Tabor, the minimum and maximum temperatures during the 2019 and 2020 cropping seasons were 7.5°C and 25.3°C, and 6.2°C and 25.5°C, respectively. Soil samples were collected from both experimental sites before the start of the experiment. Samples were taken at five spots diagonally across each site at a soil depth of 0–20 cm and then composited to characterize the overall soil parameters. The composite soil samples were analyzed at the Soil Laboratory of the Adet Agricultural Research Center. The samples were air-dried, crushed, and sieved using a 2 mm sieve to determine soil texture, total nitrogen, pH, available phosphorus, organic carbon, and cation exchange capacity. The findings of the soil analysis and the methodologies used are presented in Table 1.

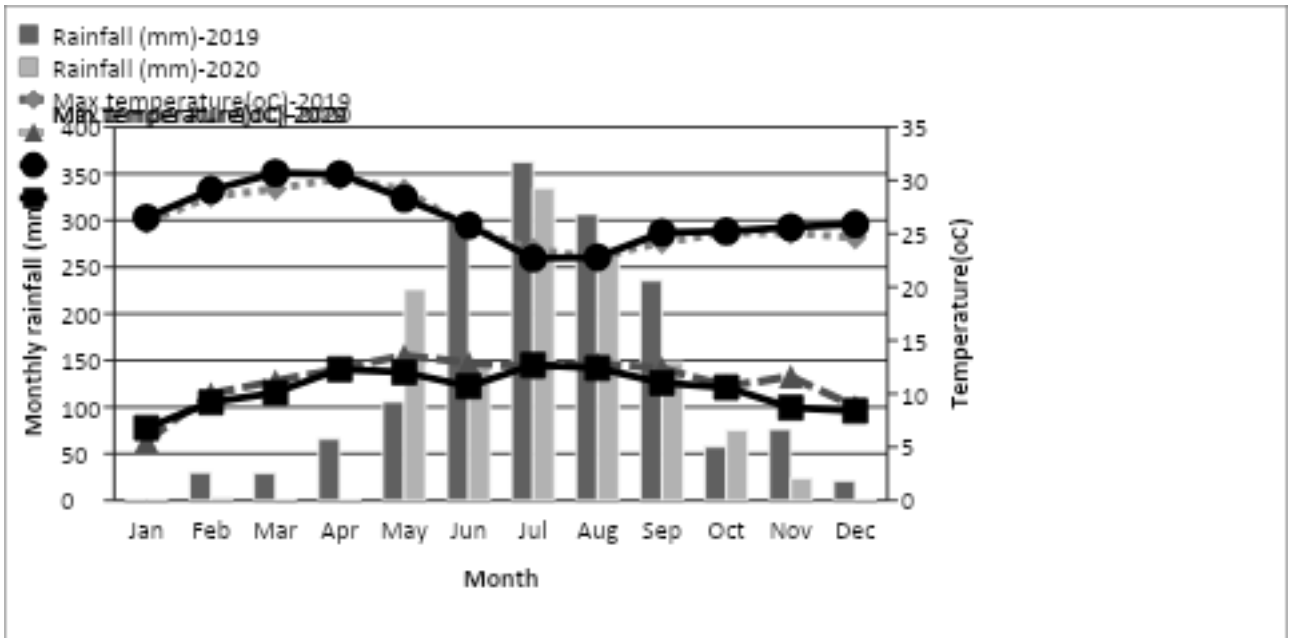

Figure 1: Average monthly rainfall and temperature distribution in Adet throughout the two-year experiment (Bahir Dar Meteorology Station, 2020)

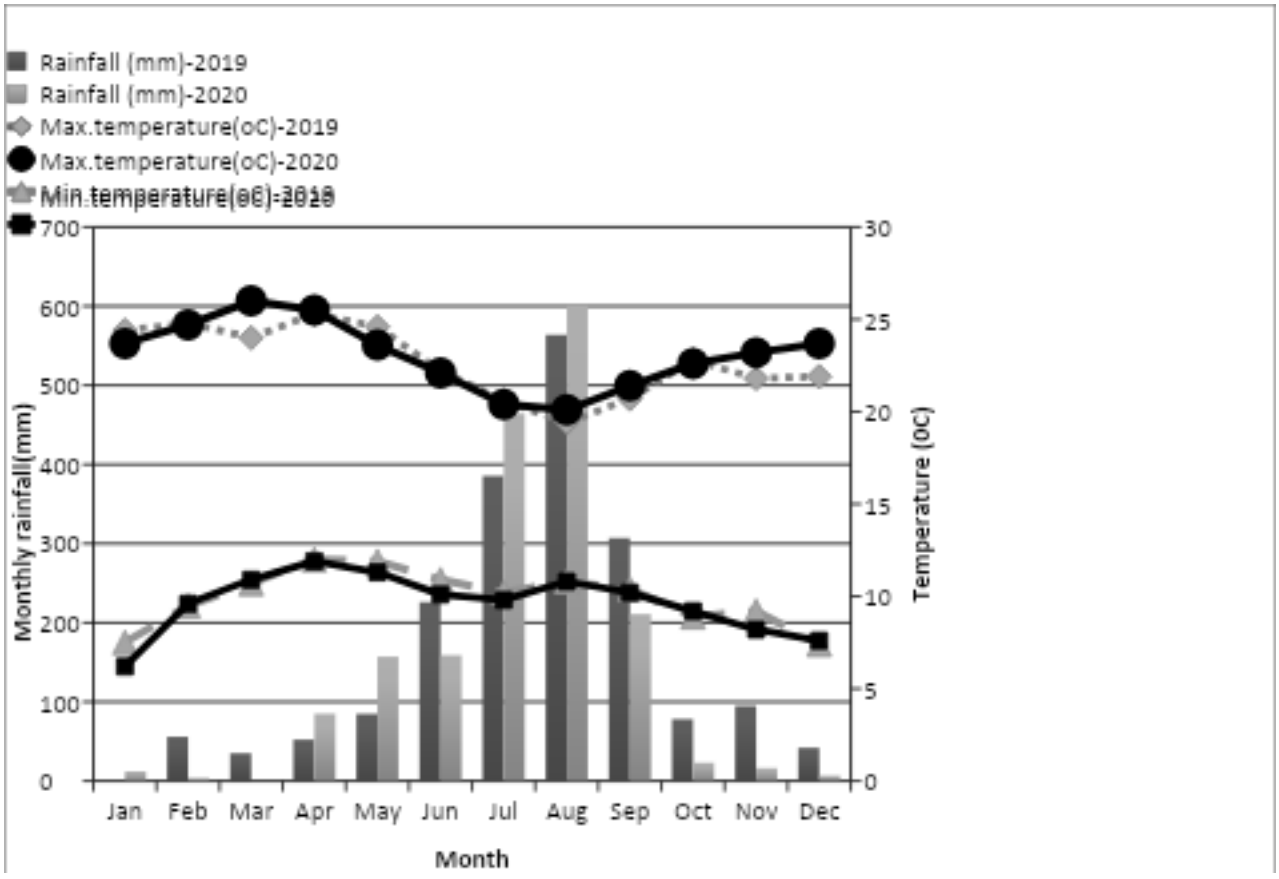

Figure 2: Average monthly rainfall and temperature distribution during the two experimental years (2019 – 2020) at Debre Tabor

2.2. Experimental Treatments, Design, and Procedures

Bread wheat was intercropped with two lupine varieties at varying planting dates at the Adet and Debre Tabor experimental sites (Table 2). The treatments included an additive series of lupine row intercropping with bread wheat at four different planting dates and two lupine varieties. Additionally, the sole cropping of each of the three crops was considered as a control. The experiments were laid out in a 4 x 2 factorial randomized complete block design (RCBD) with three replications. The sole crops of wheat, local lupine, and sweet lupine were also included for comparison. The gross and net areas of the experimental plots were 3.6 m x 2 m (7.2 m^2) and 3 m x 2 m (6 m^2), respectively, with a distance of 0.5 m between adjacent plots and 1 m between replications. The most dominant and adaptable varieties of bread wheat, local lupine (white lupine), and sweet lupine (Sanabor) were used in this study.

Bread wheat was the primary crop, while local lupine and sweet lupine served as secondary crops. These were planted simultaneously or at intervals of two, four, and six weeks after the wheat was sown. Wheat was sown on the 24th and 25th of June in 2019 and 2020, respectively. Bread wheat seeds were manually drilled in rows with a 20 cm inter-row spacing, while lupine seeds were planted in every second row at 40 cm x 10 cm inter- and intra-row spacing in an additive design (2:1) intercropping system. Fertilizer rates of 74/46 N/P_2O_5 kg ha^{-1} and 120/46 N/P_2O_5 kg ha^{-1} were applied at the Adet and Debre Tabor sites, respectively. The entire phosphorus requirement was applied at sowing in the form of Di-ammonium phosphate (DAP). Nitrogen in the form of urea was applied in two splits: one-third at sowing and the remaining two-thirds at the tillering stage, with the application in a band at a depth of 2 cm. Lupine in all cropping systems received 18/46 N/P_2O_5 kg ha^{-1} in the form of DAP at planting. Although lupine benefits from nitrogen fixation, it requires a starter fertilizer (DAP) to establish growth. Weed management was uniformly conducted by hand weeding. Fertilizer application for all crops followed the banding method at a depth of 2 cm. Following the crop establishment, weeding and other management practices were carried out as needed.

Table 1: Soil properties of the study sites before the experiment

Soil Properties	Adet		Debre Tabor		Method of Soil Analysis
	Value	Rating	Value	Rating	
pH (H_2O) 1:2.5	5.08	Moderately acidic[b]	6.24	Slightly acidic[b]	pH meter (H2O 1:2.5)
CEC[cmol(+) kg^{-1}]	38.28	High[c]	42.73	Very high[c]	Ammonium acetate method (Chapman, 1965b)
OC (%)	1.21	Very low[c]	1.48	Very low[c]	Walkley and Black method (Heanes, 1984)
TN (%)	0.17	Low[c]	0.16	Low[c]	Micro-Kjeldahl method (Bremner & Mulvaney, 1982b)
Ava. P (ppm)	3.89	low[c]	21.33	Low[c]	Bray method (Bray & Kurtz, 1945b)
Soil texture					hydrometer method (Gee & Bauder, 1986a)
Sand (%)	55	-	56	-	
Silt (%)	11	-	19	-	
Clay (%)	36	-	25	-	
Soil textural class	Sandy clay	Sandy clay[c]	Sandy clay loam	Sandy clay loam[c]	USDA Classification

NB: pH: potential of hydrogen, CEC: cation exchange capacity, OC: organic carbon, TN: total nitrogen, Ava. P: available phosphorus, USDA: the U.S. Department of Agriculture.
[a]Data were the mean of 2 years (2019 and 2020)
[b]Panda (2010)
[c]Landon (1991).

Table 2: Description of the treatment combinations for the bread wheat and sweet lupine intercropping experiment

Treatment Number	Treatments Combination		Abbreviations
	Sowing dates of lupines	Varieties of lupines	
1.	At the same time (S1)	Local lupine (V1)	S1V1
2.		Sweet lupine (V2)	S1V2
3.	Two weeks (S2)	Local lupine (V1)	S2V1
4.		Sweet lupine (V2)	S2V2
5.	Four weeks (S3)	Local lupine (V1)	S3V1
6.		Sweet lupine (V2)	S3V2
7.	Six weeks (S4)	Local lupine (V1)	S4V1
8.		Sweet lupine (V2)	S4V2
	Sole cropping (for comparison purposes)		
9.	Bread wheat		SBW
10.	Local lupine		SLL
11.	Sweet lupine		SSL

2.3. Tools of Data Collection

The number of branches per plant (NBPPL), number of pods per branch (NPOPB), and number of seeds per pod (NSEPPO) were measured at physiological maturity from ten randomly selected lupine plants within the net plot area using the row planting method. At the Adet experimental site, the days to physiological maturity from sowing to harvesting for Treatment 1, Treatment 2, Treatment 3, Treatment 4, Treatment 5, sole sweet lupine, and sole local lupine were 183, 140, 170, 127, 179, 140, and 170 days, respectively. At the Debre Tabor experimental site, the corresponding days to physiological maturity were 204, 164, 188, 156, 176, 156, and 188 days, respectively.

The total above-ground biomass (BY) of the component crops from the net plot area was collected and sun-dried for two weeks at an average air temperature of 25–27°C until fully dried. The grain yields (GY) of bread wheat and lupines were then determined from the total biomass yield. After harvesting, the grain yields were dried, threshed, cleaned, and adjusted to moisture contents of 12% for bread wheat and 14% for lupines.

2.4. Methods of Data Analysis

Data analysis for the number of branches per plant (NBPPL), number of pods per branch (NPOPB), number of seeds per pod (NSEPPO), component crop grain yield (GY), and total biomass yield (BY) was conducted using the General Linear Model (GLM) procedure of SAS version 9.2 (SAS Institute, 2008) for each site and year. The data were combined across years since the error mean squares for the two years were homogeneous (Gomez and Gomez, 1984). In the combined analysis, location and treatment were considered fixed effects, while the year was treated as a random effect. Crop characteristics that showed significant differences ($P<0.05$) were further tested for mean separation. Indices such as temporal niche differentiation, land equivalent ratio, competition ratio, and production efficiency were calculated for each treatment using their respective formulas, and the results were interpreted based on the values of these indices. Grain yields obtained on a plot basis were converted to a hectare basis and expressed in tons per hectare for statistical analysis.

i) Temporal Niche Differentiation (TND)

TND is a metric that measures how much of the intercrop's entire growing period differs from that of the two-component species when produced as a sole crop. The formula for calculating it was devised by Yu *et al*. (2015):

$$TND = \frac{P\ system - P\ overlap}{P\ system} = 1 - \left(\frac{P\ overlap}{P\ System}\right) \quad (1)$$

Where P overlap represents the period of overlap of the growth period of the intercropped species, while the P system represents the duration of the whole intercrop. In theory, TND is zero when both species are sown and harvested at the same time; TND would be one in the case of double cropping, and TND would be found between zero and one when both species are sown and harvested at the same or different dates. High temporal niche differentiation means the duration of overlap is short, the reduction of growth resource competition, and approaches one. Low temporal niche differentiation means the duration of overlap is long, high growth resource competition, and approaches zero.

ii) Land-use Efficiency

The Land Equivalent Ratio (LER) is a measure of land utilization efficiency in an intercropping system. When compared to mono-cropping, it demonstrates the efficiency of intercropping for the exploitation of environmental resources (Zhang *et al.* 2011). Willey and Reddy (1981) devised the formula for calculating the LER.

$$LER = \sum_{I=1}^{n} \left(\frac{Yi}{Ym}\right) \quad (2)$$

where Yi and Ym are yields of component crops in intercrop and sole cropping, respectively, and n is the number of crops involved. The value of unity is the critical value. When LER is equal to one, component crops are complementary. When the LER is more than one, intercropping benefits the species' development and yield. When the LER is less than one, however, intercropping harms the growth and production of plants farmed in combinations.

iii) Competitive Ratio (CR)

To quantify competitiveness among component crops, the competitive ratio was used (Zhang *et al*. 2011). The following formula was used to calculate the competitive ratio of the component crops:

$$CRW = \left(\frac{PLERW}{PLERL}\right) x \left(\frac{ZLW}{ZWL}\right) \quad (3)$$

$$CRL = \left(\frac{PLERL}{PLERW}\right) x \left(\frac{ZWL}{ZLW}\right) \quad (4)$$

$$PLERW = \frac{YWIC}{YWSC} \quad (5)$$

$$\text{PLERL} = \frac{YLIC}{YLSC} \quad (6)$$

Where CRW and CRL denote bread wheat and lupine CR, respectively. PLERW and PLERL are the partial land equivalent ratios of wheat and lupines, respectively, and ZWL and ZLW are the seed proportion of wheat intercropped with lupine varieties and the seed proportion of lupine varieties intercropped with wheat, respectively. The yields of wheat and lupine varieties in intercropping are YWIC and YLIC, respectively, while the yields of wheat and lupine varieties in sole cropping are YWSC and YLSC, respectively. Wheat was a competitor if CRW was greater than one, while lupine suppressed wheat output if CRW was less than one.

iv) Production Efficiency

The Area Time Equivalent Ratio (ATER) is a relatively new measure for determining the effectiveness of cropping systems (Samant, 2015). Hiebsch and McCollum (1987) calculated the ATER as follows:

$$ATER = \frac{(PLERW\ x\ TW)+(PLERL\ x\ TL)}{T} \quad (7)$$

Where PLERW and PLERL are the partial land equivalent ratios of wheat and lupines, respectively; TW denotes the duration of wheat maturity, TL denotes the duration of lupine maturity, and T denotes the period of the intercropping system. The null hypothesis was that ATER equaled one, implying that the two crops are complementary. When the ATER was more than one, intercropping favored the component crop growth and yield. Intercropping, on the other hand, had a detrimental impact on the component crops' development and yield when ATER was less than one. According to Jolliffe and Wanjau (1999), intercropping productivity was calculated in terms of TLO yields as the sum of the component grain yields.

3. Results and Discussion

3.1. Growth Responses of Lupines in Bread Wheat-lupine Intercropping

Growth responses of the lupines were significantly ($P<0.01$) influenced by intercropping treatments (Table 3)**.** The highest number of branches per plant (NBPPL) was observed in the local lupine planted two weeks after the bread wheat (S2V1), followed by the simultaneous planting of local lupine and bread wheat (S1V1), the planting of local lupine four weeks after bread wheat (S3V1), and the simultaneous planting of sweet lupine and bread wheat (S1V2) at the Adet Experimental site (Table 3). At the Debre Tabor experimental site, the greatest number of branches per plant was recorded with the simultaneous planting of local lupine and bread wheat (S1V1) (Table 3). In both experimental sites, the lowest number of branches per plant was recorded for the sweet lupine planted four weeks after bread wheat (S3V2), the local lupine planted six weeks after bread wheat (S4V1), and the sweet lupine planted six weeks after bread wheat (S4V2) (Table 3).

The highest number of pods per branch (NPOPB) was achieved by planting local lupine two weeks after bread wheat (S2V1) and by the simultaneous planting of sweet lupine (S1V2) and local lupine (S1V1) with bread wheat at the Adet experimental site. Similarly, at the Debre Tabor experimental site, the highest number of pods per branch was recorded with the simultaneous planting of local lupine and bread wheat (S1V1) and the planting of local lupine two weeks after bread wheat (S2V1) (Table 3). The lowest number of pods per branch was observed for the sweet lupine planted four weeks after bread wheat (S3V2), the local lupine planted six weeks after bread wheat (S4V1), and the sweet lupine planted six weeks after bread wheat (S4V2) at both experimental sites (Table 3).

At the Adet site, the simultaneous planting of local lupine (S1V1) and bread wheat, and the planting of local lupine two weeks after bread wheat (S2V1), resulted in the highest number of seeds per pod

(NSEPPO). At the Debre Tabor site, the highest NSEPPO was observed with the simultaneous planting of local lupine and bread wheat (S1V1), the planting of local lupine two weeks after bread wheat (S2V1), and the planting of local lupine four weeks after bread wheat (S3V1) (Table 3). The significantly higher yield attributes of local lupine in the bread wheat-local lupine intercropping system compared to the bread wheat-sweet lupine intercropping system across all treatments can be attributed to (i) a longer temporal niche differentiation (TND), which reduces competition for growth resources due to a shorter overlap period, and (ii) more efficient resource utilization due to the extended TND. This finding is consistent with Bitew *et al.* (2020), who reported higher grain yields in certain cereal-legume intercropping systems compared to others, likely due to longer TND.

In the bread wheat-lupine intercropping system, the lowest number of seeds per pod was recorded for sweet lupine planted four weeks after bread wheat (S3V2), local lupine planted six weeks after bread wheat (S4V1), and sweet lupine planted six weeks after bread wheat (S4V2). The poor performance in growth parameters for these treatments could be due to: (i) delayed sowing of sweet lupine seeds four weeks after the main crop, which did not provide a conducive environment for germination and growth in the bread wheat-sweet lupine intercropping system, and (ii) delayed sowing of both local and sweet lupine six weeks after the main crop, where both lupine varieties failed to sprout due to poor seed germination conditions, shading effects from the component crop, and low soil temperatures caused by persistent rainfall.

Table 3: Yield and yield attributes of legumes in bread wheat-legumes intercropping system in Northwest, Ethiopia

Intercropping Treatments			**Adet**						**Debre Tabor**					
Planting dates	Varieties	Abbreviation	TND	NBPPL	NPOPB	NSEPPO	GY	BY	TND	NBPPL	NPOPB	NSEPPO	GY	BY
At the same time (S1)	Local lupine (V1)	S1V1	0.27	3.8ab	5ab	5a	1.63a	7.68a	0.23	5a	6a	4.8a	2.6a	6a
	Sweet lupine (V2)	S1V2	0.05	3.5b	5.3a	4.67b	1.05c	4.57c	0.08	3.5b	3.7c	4bc	1.3b	2.9b
Two weeks (S2) later	Local lupine (V1)	S2V1	0.34	4.3a	5.3a	5a	1.46ab	5.79b	0.30	4b	5.3ab	4.5ab	2.5ab	4.8ab
	Sweet lupine (V2)	S2V2	0.14	2.5c	4c	4c	0.69d	3.17d	0.17	3.8b	4.3bc	3.8c	1.5ab	3.3b
Four weeks (S3)	Local lupine (V1)	S3V1	0.48	3.5b	4.3bc	4.67b	1.32b	5.49b	0.36	4b	4.5bc	4.5ab	2.4ab	4.9ab
	Sweet lupine (V2)	S3V2	-	0d	0d	0d	0e	0e	-	0c	0d	0d	0c	0c
Six weeks (S4)	Local lupine (V1)	S4V1	-	0d	0d	0d	0e	0e	-	0c	0d	0d	0c	0c
	Sweet lupine (V2)	S4V2	-	0d	0d	0d	0e	0e	-	0c	0d	0d	0c	0c
LSD			-	0.71***	0.83***	0.3***	0.25***	0.48***	-	0.95***	1.37***	0.54***	1.2***	2.64***
CV%			-	23	23	9	7	6	-	26	24	13	14	11.5
SE±				0.67	0.89	0.83	0.25	0.41		0.76	0.9	0.6	0.4	0.87

NB: temporal niche differentiatio (TND); the number of branches per plant (NBPPL); the number of pods per branch (NPOPB); the number of seeds per pod (NSEPPO); grain yield (GY); total biomass yield (BY). GY & BY expressed in ton per hectare (t ha^{-1})
Data were combined over the years (2019 and 2020).
*, **, *** are the significant differences at a probability level of 0.05, 0.01, and 0.001, respectively. Means with the same letter are not significantly different within columns.

3.2. Yield Responses of Lupine under Bread Wheat-lupine Intercropping

The highest grain yields were recorded for the simultaneous planting of local lupine (S1V1) and bread wheat, and for the planting of local lupine two weeks after bread wheat (S2V1), followed by the treatments S3V1, S1V2, and S2V2 at the Adet experimental site (Table 3). At Debre Tabor, only the simultaneous planting of local lupine (S1V1) and bread wheat produced significantly higher grain yields compared to the simultaneous planting of sweet lupine (S1V2) and bread wheat (Table 3).

The highest total biomass yield was achieved with the simultaneous planting of local lupine (S1V1) and bread wheat, followed by the planting of local lupine two weeks (S2V1) and four weeks (S3V1) after bread wheat at Adet (Table 3). At Debre Tabor, the highest total biomass yields were similarly recorded for the simultaneous planting of local lupine (S1V1) and bread wheat, and for planting local lupine two weeks (S2V1) and four weeks (S3V1) after bread wheat. However, the simultaneous planting of local lupine (S1V1) and bread wheat yielded greater biomass than the simultaneous planting of sweet lupine (S1V2) and bread wheat, as well as planting sweet lupine two weeks after bread wheat (S2V2) (Table 3).

When compared to short temporal niche differentiation (TND) intercropping treatments, long TND intercropping treatments produced the maximum grain yield and total biomass. This could be due to (i) reduced inter-specific competition in intercropping treatments with high TND, or (ii) the shadowing effect of the component crop being less pronounced with local lupine compared to sweet lupine, thus allowing for more efficient photosynthesis. This finding aligns with Bitew *et al.* (2020), who suggested that greater grain yields in certain intercropping treatments could be attributed to more efficient resource usage due to a longer TND. Similarly, intercrops of different varieties are widely adopted to exploit the length of the growing period (Lithourgidis *et al.* 2011) and to increase light interception over time (Keating and Caberry, 1993; Zhang *et al.* 2008). Lupines planted four weeks later, and sweet lupines planted six weeks later in the bread wheat-lupine intercropping system produced the lowest grain yields and total biomass. This could be attributed to minimal interspecific competition and high TND in these treatments.

3.3. Land Use Efficiency in Bread Wheat-lupine Intercropping

The partial land equivalent ratio (PLER) of bread wheat was greater than 0.5 in all treatments at both experimental sites. In contrast, the PLER for lupines was less than 0.5 at Adet but greater than 0.5 at

Debre Tabor (Table 4). PLER values exceeding 0.5 for both cereal and legume crops suggest that both component crops benefited from enhanced growth resource utilization during their co-growing period in these cereal-based intercropping systems (Bitew *et al*. 2019). A PLER of less than 0.5 for lupines indicates that bread wheat had a competitive advantage, while lupines were at a disadvantage in this intercropping system. Conversely, the higher PLER of bread wheat compared to legumes demonstrates its stronger competitive ability. Consequently, bread wheat contributed more to the combined yield and land equivalent ratio (LER), supporting the farmers' practice of cultivating legumes as an intercrop. This finding is consistent with previous studies, such as Wang *et al.* (2017) on wheat-faba bean intercropping and Guiducci *et al.* (2018) on winter wheat legumes. Similarly, Yadav and Yadav (2010) observed a yield advantage in pearl millet-cluster bean intercropping.

Table 4: Yield and yield attributes of legumes in bread wheat-legumes intercropping system in Northwest, Ethiopia

Intercropping Treatments			Adet						Debre Tabor					
Planting dates	Varieties	Abbreviation	TND	NBPPL	NPOPB	NSEPPO	GY	BY	TND	NBPPL	NPOPB	NSEPPO	GY	BY
At the same time (S1)	Local lupine (V1)	S1V1	0.27	3.8ab	5ab	5a	1.63a	7.68a	0.23	5a	6a	4.8a	2.6a	6a
	Sweet lupine (V2)	S1V2	0.05	3.5b	5.3a	4.67b	1.05c	4.57c	0.08	3.5b	3.7c	4bc	1.3b	2.9b
Two weeks (S2) later	Local lupine (V1)	S2V1	0.34	4.3a	5.3a	5a	1.46ab	5.79b	0.30	4b	5.3ab	4.5ab	2.5ab	4.8ab
	Sweet lupine (V2)	S2V2	0.14	2.5c	4c	4c	0.69d	3.17d	0.17	3.8b	4.3bc	3.8c	1.5ab	3.3b
Four weeks (S3)	Local lupine (V1)	S3V1	0.48	3.5b	4.3bc	4.67b	1.32b	5.49b	0.36	4b	4.5bc	4.5ab	2.4ab	4.9ab
	Sweet lupine (V2)	S3V2	-	0d	0d	0d	0e	0e	-	0c	0d	0d	0c	0c
Six weeks (S4)	Local lupine (V1)	S4V1	-	0d	0d	0d	0e	0e	-	0c	0d	0d	0c	0c
	Sweet lupine (V2)	S4V2	-	0d	0d	0d	0e	0e	-	0c	0d	0d	0c	0c
LSD			-	0.71***	0.83***	0.3***	0.25***	0.48***	-	0.95***	1.37***	0.54***	1.2***	2.64***
CV%			-	23	23	9	7	6	-	26	24	13	14	11.5

SE±	0.67	0.89	0.83	0.25	0.41	0.76	0.9	0.6	0.4	0.87

The Land Equivalent Ratio (LER) was greater than or equal to one in almost all intercrops at both experimental sites. However, at Debre Tabor, the LER was lower than that of the sole crop for the planting of sweet lupine four weeks (S3V2) after bread wheat, local lupine six weeks (S4V1) after bread wheat, and sweet lupine six weeks (S4V2) after bread wheat. This was due to the failure of the legumes to germinate, grow, or contribute to the overall land output yield in these intercropping systems (Table 4). At Adet, all LER values were greater than or equal to one. The highest LER at Adet was observed for S1V2 (1.3), followed by S2V2 (1.23) in the bread wheat-lupine intercropping system. At the Debre Tabor experimental site, the highest LER values were recorded for S2V2 (1.67), followed by S1V2 (1.6), S2V1 (1.6), and S3V1 (1.6) in the bread wheat-lupine intercropping system (Table 4).

The higher LER in most bread wheat-legume intercropping scenarios, except for S1V2 and S2V2 at Adet, can be attributed to the wider Temporal Niche Differentiation (TND) between intercropped crops, resulting in reduced inter-specific competition. This finding aligns with Bitew *et al.* (2019), who reported that greater TND leads to less inter-specific competition in cereal-legume intercropping systems. Additionally, intercropping can enhance nutrient availability and efficiency, improving overall land output yield (Kiwia *et al.* 2019). Sweet lupine intercropping, particularly simultaneous planting and planting two weeks after bread wheat, yielded higher LER compared to local lupine in bread wheat-local lupine intercropping. Vandermeer (1989) noted that intercropping systems often involve both competition and facilitation, and achieving an LER greater than one suggests that facilitative interactions can outweigh competitive interference.

The results indicate that sole cropping would require 23 to 30% more land in Adet and 60 to 67% more land in Debre Tabor, implying that intercrop systems can provide a yield advantage of 60 to 67% over sole cropping. This enhanced yield and land-use efficiency suggest that farmers could achieve higher productivity without increasing land area, thus diversifying food and revenue sources for households. This finding is consistent with other research, including finger millet-white lupine intercropping systems (Bantie *et al.* 2014), pearl millet-cluster bean intercropping systems (Yadav and Yadav, 2001), and pea-barley intercropping systems (Chen *et al.* 2004). In contrast, S3V2, S4V1, and S4V2 at Debre Tabor resulted in yield reductions of 7%, 5%, and 7%, respectively, compared to sole cropping, primarily due to the reduced yield of component crops. The LER values for S3V2, S4V1, and S4V2 at Debre Tabor were all less than

one, indicating these combinations were less effective than the respective sole crops. Similar findings were reported for wheat-pea (Naudin *et al.* 2010) and barley-lupine (Bantie *et al.* 2014) intercropping systems. This underscores the need for selecting appropriate component crops and planting dates to enhance production in intercropping systems.

3.4. Competition between Component Crops

At both study sites, bread wheat exhibited greater competitiveness (Competition Ratio for Bread Wheat, CRBW, ranging from 1.08 to 4.8) compared to sweet lupine (CRSL, ranging from 0.24 to 0.88) and local lupine (CRLL, ranging from 0.21 to 0.92) in the bread wheat-lupine intercropping systems (Table 5). Zhang *et al.* (2014) indicated that if the CR of a cereal is greater than one, the cereal is considered a competitor, whereas a CR of less than one suggests that the legume crop suppresses cereal production. In all intercropping experiments, bread wheat consistently demonstrated a higher CR compared to both sweet lupine and local lupine. This higher CR for bread wheat can be attributed to its rapid growth and the high number of tillers, which likely outcompete the lupines. This finding contrasts with the results reported by Bantie *et al.* (2014) in cereal-legume intercropping studies.

In the bread wheat-lupine intercropping treatments, competition for resources was lower for lupines, as evidenced by CRLL values of 0.21 and 0.72 at Adet and Debre Tabor, respectively (Table 5). This reduced competition is associated with the wider Temporal Niche Differentiation (TND) observed at Adet (0.48) and Debre Tabor (0.36) (Table 3). Yu *et al.* (2015) noted that intercropping systems with a large TND experience lower competition for growth resources. Local lupine competition was less pronounced, ranging from 0.31 to 0.21 at Adet and from 0.92 to 0.72 at Debre Tabor in bread wheat-local lupine intercropping treatments, while TND ranged from 0.27 to 0.48 and 0.23 to 0.36, respectively (Table 3). Similarly, in bread wheat-sweet lupine intercropping treatments, as TND increased from 0.05 to 0.14 at Adet and from 0.08 to 0.17 at Debre Tabor, the competition for sweet lupine decreased from 0.38 to 0.24 at Adet, though not significantly at Debre Tabor (Table 5).

3.5. Production Efficiency

At both study sites, the Average Total Efficiency Ratio (ATER) was higher when bread wheat was intercropped with sweet lupine compared to local lupine (Table 6). Legume intercropping can enhance soil fertility by increasing the amount of nitrogen fixed by rhizobacteria, which then

remains in the upper soil layers and becomes available to plants (Hauggaard-Nielsen *et al.* 2009; Chapagain & Riseman, 2014).

The greatest ATER was observed for the simultaneous planting of sweet lupine (S1V2) and bread wheat (1.29), followed by the planting of sweet lupine two weeks after bread wheat (S2V2) with an ATER of 1.22 at the Adet site. At Debre Tabor, the highest ATER of 1.53 was recorded for planting sweet lupine two weeks after bread wheat (S2V2), with the simultaneous planting of sweet lupine (S1V2) following at 1.39 (Table 6). This indicates that sole cropping would require 29% to 53% more area to achieve the same yield as intercropping. This variation is attributed to the climatic differences between Adet and Debre Tabor, as shown in Figures 1 and 2. The increased crop output from intercropping compared to sole cropping is also associated with higher land-use efficiency for the intercrop (Table 4).

Interspecific interactions in legume-cereal systems enable cereals to acquire more soil nitrogen, which stimulates legumes to fix more nitrogen, thus improving the overall land-use efficiency (Li *et al.* 2013). This finding aligns with previous research on cereal-legume intercropping systems (Bantie *et al.* 2014).

Table 5: Effects of intercropping treatments on land use efficiency in Northwest, Ethiopia

Intercropping Treatments			**Adet**				**Debre Tabor**			
Planting dates	Varieties	Abbreviation	PLERBW	PLERLL	PLERSL	**LER**	PLERBW	PLERLL	PLERSL	**LER**
At the same time (S1)	Local lupine (V1)	S1V1	0.80	0.25	-	1.05	0.78	0.72	-	1.5
	Sweet lupine (V2)	S1V2	0.94	-	0.36	1.3	0.91	-	0.68	1.6
Two weeks (S2) later	Local lupine (V1)	S2V1	0.99	0.23	-	1.22	0.91	0.69	-	1.6
	Sweet lupine (V2)	S2V2	0.99	-	0.24	1.23	0.89	-	0.78	1.67
Four weeks (S3)	Local lupine (V1)	S3V1	1.01	0.21	-	1.22	0.93	0.67	-	1.6

	Sweet lupine (V2)	S3V2	1.05	-	0	1.05	0.93	-	0	0.93
Six weeks (S4)	Local lupine (V1)	S4V1	1.02	0	-	1.02	0.95	0	-	0.95
	Sweet lupine (V2)	S4V2	1.00	-	0	1.00	0.93	-	0	0.93
Sole bread wheat		SBW	1.00	-	-	1.00	1	-	-	1
Sole local lupine		SLL	-	1.00	-	1.00	-	1	-	1
Sole sweet lupine		SSL	-	-	1.00	1.00	-	-	1	1
SE±			0.02	0.19	0.23	0.03	0.04	0.2	0.18	0.09

NB: [a]Data were combined over years (2019 and 2020)

PLERBW: partial land equivalent ratio of bread wheat, PLERLL: partial land equivalent ratio of local lupine, PLERSL: partial land equivalent ratio of sweet lupine, LER: land equivalent ratio in Adet and Debre Tabor experimental sites.

Table 6: Competitive ratio of bread wheat, local lupine, and sweet lupine intercropped at Adet and Debre Tabor experimental sites

Intercropping Treatment			**Adet**			**Debre Tabor**		
Planting dates	varieties	Abbreviation	CRBW	CRLL	CRSL	CRBW	CRLL	CRSL
At the same time (S1)	Local lupine (V1)	S1V1	3.20	0.31	-	1.08	0.92	-
	Sweet lupine (V2)	S1V2	2.61	-	0.38	1.33	-	0.75
Two weeks (S2) later	Local lupine	S2V1	4.30	0.23	-	1.32	0.76	-
	Sweet lupine	S2V2	4.13	-	0.24	1.14	-	0.88
Four weeks (S3)	Local lupine	S3V1	4.81	0.21	-	1.39	0.72	-
	Sweet lupine	S3V2	-	-	-	-	-	-
Six weeks (S4)	Local lupine	S4V1	-	-	-	-	-	-
	Sweet lupine	S4V2	-	-	-	-	-	-
Sole Bread wheat		SBW	-	-	-	-	-	-

Sole local lupine		SLL						
Sole sweet lupine		SSL						
SE ±			0.39	0.4	0.09	0.06	0.05	0.09

NB: CRBW: Competitive ratio of bread wheat in intercropping, CRSL: competitive ratio of sweet lupine in intercropping, CRLL: competitive ratio of local lupine in intercropping. Data were combined over the years (2019 and 2020) at both locations.

All bread wheat-lupine intercrops demonstrated ATER values greater than one at both locations, except for simultaneous planting of local lupine (S1V1) and bread wheat, planting local lupine two weeks (S2V1) after bread wheat, and planting local lupine four weeks (S3V1) after bread wheat at Adet, indicating that these combinations performed better than sole crops (Table 7).

Similar yield advantages have been observed in other non-legume-legume intercropping systems, such as bean-wheat (Hauggaard-Nielsen, 2001), groundnut-cereal fodders (Ghosh, 2004), barley-pea (Chen *et al.,* 2004), and faba bean-barley (Trydemanknudsen *et al.,* 2004). Conversely, an ATER of less than one has been reported in wheat-pea intercropping (Naudin *et al.* 2010), which contrasts with the results of this study.

Table 7: Production efficiency of bread wheat-legume intercropping in Northwest Ethiopia

Intercropping Treatments			**Adet**	**Debre Tabor**
Planting dates	**Varieties**	**Abbreviation**	**ATER**	**ATER**
At the same time (S1)	Local lupine (V1)	S1V1	0.79	1.19
	Sweet lupine (V2)	S1V2	1.29	1.39
Two weeks (S2) later	Local lupine (V1)	S2V1	0.93	1.32
	Sweet lupine (V2)	S2V2	1.22	1.53
Four weeks (S3)	Local lupine (V1)	S3V1	0.91	1.28
	Sweet lupine (V2)	S3V2	-	-
Six weeks (S4)	Local lupine (V1)	S4V1	-	-
	Sweet lupine (V2)	S4V2	-	-
Sole bread wheat		SBW	-	-
Sole local lupine		SLL	1	1
Sole sweet lupine		SSL	1	1
SE±			0.06	0.07

NB: ATER: Area time equivalent ratio; data were combined over years (2019 and 2020) at both locations.

4. Conclusion

The highest Land Equivalent Ratio (LER) was observed for the simultaneous planting of sweet lupine (S1V2) and bread wheat at the Adet experimental site (1.3), while at the Debre Tabor site, planting sweet lupine two weeks after bread wheat (S2V2) achieved the highest LER of 1.67.

Bread wheat consistently outcompeted both sweet lupine and local lupine in intercropping systems at both study sites. The Area Time Equivalent Ratio (ATER) was higher when bread wheat was intercropped with sweet lupine compared to local lupine. Specifically, the simultaneous planting of sweet lupine (S1V2) and bread wheat had the highest ATER of 1.29 at Adet, whereas at Debre Tabor, planting sweet lupine two weeks after bread wheat (S2V2) yielded the highest ATER of 1.53.

Based on these findings, it is recommended to use the simultaneous planting of sweet lupine (S1V2) and bread wheat at Adet for enhanced productivity and production efficiency. For Debre Tabor, the planting of sweet lupine two weeks after bread wheat (S2V2) is suggested to improve productivity, production efficiency, and enhance family food security in the study areas and similar agro-ecological regions.

Future research should focus on:

1. Evaluating the quality of bread wheat in intercropping systems using additive series intercropping, and
2. Assessing the impact of bread wheat and legume intercropping on soil physical, chemical, and biological properties, as well as on water use efficiency.

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The Effect of Digital Financial Services on Financial Inclusion in the Ethiopian Banking Industry

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Abstract

The expansion of digital financial services (DFS) has significantly enhanced financial inclusion across the globe. However, Ethiopia continues to lag, despite recent improvements. Existing research on DFS in Ethiopia has primarily focused on supply-side perspectives, leaving a gap in understanding demand-side determinants. This study examines the effect of digital financial services on financial inclusion in the Ethiopian banking industry, employing access, quality, and trust as key indicators of inclusion. Descriptive and explanatory research designs, combined with a mixed-methods approach, were used. A mixed sampling technique was applied to select 175 respondents, and both primary and secondary data were analyzed. The study considered accessibility, innovation, convenience, perceived benefits of use, trust, performance, and awareness as determinants of DFS. Findings reveal that all variables, except convenience, have a positive and significant effect on financial inclusion. Convenience, while positively correlated, has not yielded a statistically significant effect. The study concludes that DFS plays a vital role in promoting financial inclusion in Ethiopia's banking sector. It recommends that banks improve problem-resolution efficiency, enhance transparency regarding risks, build trust, raise awareness, and promote the benefits of DFS through community channels and public figures. Furthermore, the government should strengthen infrastructure and mandate inclusive DFS implementation across all communities.

Keywords: Digital financial services, financial inclusion, banking industry, Ethiopia, access, trust

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1. Introduction

The growing adoption of digital financial services (DFS) and fintech has emerged as a key driver of financial inclusion worldwide. By expanding access, reducing transaction costs, and offering innovative channels, DFS has created opportunities for underserved populations to participate in

the formal financial system. From this perspective, identifying the determinants of DFS that significantly contribute to financial inclusion is essential, particularly in developing economies such as that of Ethiopia. Despite global progress, Ethiopia continues to perform poorly in financial inclusion relative to its Sub-Saharan African peers (Boateng, 2022). While some studies have examined DFS from the supply side, little empirical evidence exists on its demand-side effects in the Ethiopian banking sector. This study, therefore, focuses on the role of trust, convenience, accessibility, perceived usefulness, innovation, performance, and awareness in shaping financial inclusion.

A DFS ecosystem enhances financial inclusion when services are accessible, innovative, user-friendly, trusted, and supported by strong awareness campaigns (Ozili, 2018). Several Sub-Saharan African countries have made remarkable progress in this regard, largely due to mobile money adoption. By contrast, Ethiopia's DFS penetration remains low, constrained by weak mobile money infrastructure, frequent network interruptions, limited internet access, and high service costs (Alemu, Ferede & Fiorito, 2021; Ayanaw, 2019).

According to the World Bank Findex 2017 (cited in Asli *et al*. 2018), only 35% of Ethiopian adults owned a bank account, compared to 82% in Kenya and 50% in Rwanda. Structural barriers—including low levels of digital literacy, unreliable electricity supply, and concentration of financial networks in urban areas—further limit progress (Asli *et al*. 2018; Getie, 2020). Moreover, cultural reliance on informal savings groups, such as '*iqub'*, reduces incentives to adopt formal financial services (Bessir, 2018).

The lack of demand-side research leaves critical questions unanswered regarding how DFS influences access, quality, and usage of financial services in Ethiopia. This study aims to fill in some of the knowledge gaps by addressing the following research questions:

1. To what extent do DFS (card banking, mobile banking, and internet banking) enhance financial inclusion from the demand-side perspective of accessibility and innovation?
2. How does DFS contribute to financial inclusion from the perspective of quality (convenience, trust, performance, and awareness)?
3. Does the use of DFS enhance financial inclusion from the demand-side perspective of perceived benefits?

4. What is the current level of DFS adoption in Ethiopia?

To address these questions, the study tested the following hypotheses:

H1: Accessibility of DFS positively and significantly affects financial inclusion.

H2: Innovations in DFS positively and significantly affect financial inclusion.

H3: The convenience of DFS positively and significantly affects financial inclusion.

H4: Perceived benefits of DFS usage positively and significantly affect financial inclusion;

H5: Trust in DFS positively and significantly affects financial inclusion.

H6: DFS performance positively and significantly affects financial inclusion, and

H7: Awareness of DFS positively and significantly affects financial inclusion.

By testing these hypotheses, this study hoped to contribute to the limited body of demand-side research on DFS in Ethiopia, offering both theoretical insights and practical policy recommendations to accelerate financial inclusion.

2. Review of Related Literature

2.1.Concepts and Definitions

Digital financial services (DFS) broadly refer to saving, accessing credit and insurance, and conducting transactions through digital channels such as mobile phones, cards, computers, and tablets. From a practitioner's perspective, DFS are delivered through mobile phones, personal computers, the internet, or cards linked to a reliable digital payment system (Ozili, 2018). These services are typically classified into card banking, mobile banking, and internet banking (Dashen Bank, 2015). DFS provides convenient platforms for individuals, households, and businesses to conduct financial transactions, including utility payments, fund transfers, and savings.

However, DFS also faces challenges. These include limited accessibility for excluded populations (Mishar & Kumar, 2018), voluntary exclusion by potential users (Ozili, 2018), and discriminatory marketing practices targeting higher-income customers at the expense of low-income groups (Boshkov, 2019). Generational differences also shape DFS adoption. Younger population's digital natives, such as millennials and Generation Z, are more comfortable with technology and, therefore, more inclined to adopt digital-first services (Chivers, 2021). In Sub-Saharan Africa, only 26% of youth (aged 15–24) hold financial accounts, yet mobile phone

penetration reaches as high as 83% in countries like Kenya. This suggests that the youth may bypass traditional financial products in favor of app-based solutions, creating a significant opportunity for innovative companies that traditional banks have often overlooked (Njoroge, 2016).

Financial inclusion focuses on integrating the "unbanked" population into the formal financial system by providing access to savings, payments, transfers, credit, and insurance (Boshkov, 2019). Greater access enables households to participate in economic activities and supports the achievement of the Sustainable Development Goals (SDGs). Recognizing this, international initiatives such as the Maya Declaration on Financial Inclusion (2011)—developed by the Alliance for Financial Inclusion (AFI)—have sought to improve financial access for the world's poorest populations (Negussie, 2020). DFS plays a central role in this agenda by enabling underserved populations to perform essential transactions remotely, thereby reducing barriers to participation (Gupta & Arya, 2020).

According to AFI (2019), DFS can be assessed across three core dimensions of financial inclusion. The core dimensions are access, usage, and quality.

'Access' refers to the ability of institutions to deliver financial products and services, influenced by regulation, market structure, and technology, while ***'usage'*** denotes the frequency, duration, and manner in which clients use services (e.g., savings balances, number of transactions, digital payments). And '***quality'*** marks the extent to which services meet users' needs effectively.

DFS, therefore, creates a "win–win" situation by simultaneously expanding financial inclusion and offering inexpensive, secure, and convenient services (Gujral & Kumar, 2021). While numerous studies have examined financial inclusion broadly, relatively few have investigated the specific effect of DFS on financial inclusion, particularly in developing economies.

2.2.Current Magnitude of Digital Financial Services in Ethiopia

Ethiopian banks have made notable progress in expanding DFS infrastructure, with the following institutions serving as illustrative examples.

Bank of Abyssinia (BOA): In 2020/21, BOA deployed 740 new ATMs, bringing the total to 969. Card banking users increased to 987,984, mobile banking subscribers reached 910,969, and

online banking subscribers rose to 8,286. However, the number of Point of Sale (POS) terminals increased only slightly, from 281 to 300 (Bank of Abyssinia, 2021).

Awash Bank: During 2020/21, Awash Bank expanded its DFS infrastructure by adding 97 ATMs, 825 POS terminals, and 77 agents, reaching totals of 565, 1,406, and 104, respectively (Awash Bank, 2021).

Commercial Bank of Ethiopia (CBE): By 2020, CBE deployed 567 new ATMs, redeployed 182 POS machines, and issued 2.7 million new ATM cards. Additionally, it enrolled 2.3 million new mobile banking users, 8,100 internet banking subscribers, and 2.3 million CBE *Birr* mobile money users. Digital channels processed 163 million transactions worth ETB 198.5 billion, representing 37% of the bank's total transaction volume (Commercial Bank of Ethiopia, 2020).

Dashen Bank: By 2021, Dashen Bank operated 1,340 POS terminals and 403 ATMs. Its cardholders reached 1.3 million, reflecting an 18.2% annual growth. The *Amole* digital platform added 443,586 new subscribers, raising the total to 2.4 million. During the year 552,000 *Amole* transactions worth ETB 2.3 billion were processed, and the number of *Amole* merchants reached 8,119 (Dashen Bank, 2021).

***Nib* International Bank:** At the end of 2020/21, *Nib* operated 170 ATMs and 394 POS terminals. The bank distributed 184,076 new ATM cards, bringing the total number of cardholders to 505,059, representing 30.2% of its total account holders (Nib International Bank, 2021).

Overall, the figures indicate a growing, but uneven expansion of DFS infrastructure across Ethiopian banks, with mobile and card-based platforms showing faster adoption than internet banking.

2.3.Empirical Review

Empirical studies from different contexts highlight the positive relationship between DFS and financial inclusion. In Indonesia, Widarwati, Solihin, and Nurmalasari (2022) developed a new measurement termed "average digital finance" (ADF) to assess DFS impacts. Their findings confirmed that DFS positively influences financial inclusion, with bank size moderating the relationship.

In Tanzania, Lyimo and Mbesigwe (2022) reported that DFS significantly enhances financial inclusion by increasing accessibility and usage. In India, Gujrat and Kumar (2021) found that accessibility, simplicity, and affordability of DFS positively affected mobile banking and mobile wallet adoption, thereby supporting financial inclusion.

In Ethiopia, Negussie (2020) examined the role of DFS and fintechs in financial inclusion, focusing on government support, regulatory frameworks, and expansion challenges. The study concluded that Ethiopia's DFS contribution to financial inclusion remains weak due to regulatory and infrastructural barriers.

Regarding other global contexts, Durai (2019) found that usability, convenience, accurate timing, and interbank facilities significantly influenced mobile banking adoption, while low service charges affected mobile wallet use. Similarly, Boshkov (2019) emphasized that provider proximity, convenience, and distribution networks positively impact financial inclusion. Ozili (2018) highlighted that while DFS generally promotes inclusion, the relationship may be non-linear, with low-income users facing higher risks of exclusion due to affordability and literacy barriers.

Overall, the empirical evidence suggests that DFS generally enhances financial inclusion, though effectiveness depends on affordability, awareness, infrastructure, and regulatory support.

3. Research Methodology

3.1. Research Design

This study examined the effect of digital financial services (DFS) on financial inclusion in the Ethiopian banking industry. To achieve this, descriptive and explanatory research designs were employed. The descriptive component focused on illustrating the current magnitude of DFS adoption, while the explanatory component investigated the cause-and-effect relationship between DFS and financial inclusion.

A mixed-method approach was adopted, specifically a convergent parallel design. In this design, both quantitative and qualitative data were collected separately, but concurrently through questionnaires and interviews. The quantitative data were analyzed using statistical procedures and hypothesis testing with the Statistical Package for the Social Sciences (SPSS). The qualitative data were analyzed thematically. Finally, results from both approaches were

converged by comparing and contrasting the findings within a single interpretive framework. This design allowed for triangulation, enhancing validity by integrating quantitative (QUAN) results with qualitative (QUAL) insights and empirical evidence.

3.2.Data and Sampling

i) Data Collection

Primary data were collected using two instruments: questionnaires and interviews. Questionnaires were distributed to DFS users registered with commercial banks in Addis Ababa branch offices, and to DFS users originally registered in other regions, but currently accessing services in Addis Ababa. In addition, semi-structured interviews were conducted with professionals working in purposely selected bank branches.

Secondary data were collected from multiple sources, including reports from the World Bank, National Bank of Ethiopia (NBE), and UNDFC, as well as academic journal articles, annual reports of Ethiopian financial institutions, research studies, books, newspapers, and relevant websites. These data provided a contextual understanding of DFS trends and banking sector developments.

ii) Sampling

The study used a mixed sampling technique. First, five major commercial banks were selected purposely: Commercial Bank of Ethiopia, Dashen Bank, Bank of Abyssinia, Awash Bank, and Nib International Bank. These institutions were chosen due to their leading role in DFS provision. Within these banks, DFS users were selected through a random sampling technique to complete questionnaires, while bank professionals were approached again purposely for interviews.

According to the National Bank of Ethiopia (2021), there were 2,528 commercial bank branches in Addis Ababa. The sample size was determined using the Response Amplitude Operator (RAO) formula (1985) with a 92.44% confidence level, and a 7.56% margin of error. The calculation is as follows:

$$n = \frac{4*p*q}{L^2}$$

Where:

n = the required sample size

p = the approximate prevalence rate for which the survey is to be conducted, which is 50%

q = (1-p), which is 50%

L^2= permissible error (margin of error) in the estimate, which is 7.56%

=4*0.5*0.5 / 0.07562

= 174.97

Accordingly, the final sample size was set at 175 respondents.

iii) Model Specification and Variables

Since the dependent variable—financial inclusion—is binary in nature, a binary logistic regression model was employed. This approach was chosen because logistic regression is specifically designed for dichotomous outcomes and does not require the assumptions of normality, homoscedasticity, or linearity that ordinary least squares (OLS) regression demands (Hosmer, Lemeshow, & Sturdivant, 2013). Using linear regression for binary outcomes often produces biased, inefficient, and invalid probability estimates, whereas logistic regression provides a more robust and theoretically sound estimation.

The model estimates the probability that an individual is financially included (Y = 1) versus not included (Y = 0). It is specified as:

$$\Pi = P\,(Yi = 1/Xi) = \frac{e^{(\beta_0 + \beta_1 A + \beta_2 NI + \beta_3 A + \beta_4 A^2 + \beta_5 A + \beta_6 A + \beta_7 A^2)}}{1 + e^{(\beta_0 + \beta_1 A + \beta_2 NI + \beta_3 A + \beta_4 A^2 + \beta_5 A + \beta_6 A + \beta_7 A^2)}}$$

Where:

π is the probability that an individual is financially included,

Y is the Binary response dependent variable (financial inclusion),

B0 is the Constant of the binary logistic regression equation.

A is accessibility,

NI is innovation,

C is Convenience,

PBU is the perceived benefit of usage,

T is Trust,

P is Performance, and

AW is Awareness.

The model assumes a logit link function, which transforms the binary outcome into a log-odds metric, allowing for the estimation of non-linear relationships between DFS variables and financial inclusion. The study hypothesized that DFS variables (accessibility, innovation, convenience, perceived benefit, trust, performance, and awareness) have a positive and significant effect on financial inclusion.

4. Results and Discussion

4.1. Demographic Characteristics of Respondents

The demographic profile of the respondents provides important context for understanding the patterns of digital financial service (DFS) adoption in Ethiopia. Out of the total sample of 175, 49.4% of the respondents were male, while 50.6% were female, indicating a nearly equal gender representation. Regarding age distribution, over one-third of the respondents were aged 25–34 (36.5%), with those aged 18–24 comprising the next largest group (33.3%). This highlights that younger and economically active age groups are the main users of DFS, reflecting both the demographic structure of the urban population and the increasing digital orientation of younger cohorts.

Marital status results show that most of the respondents were married (51.3%), while a considerable proportion were single (47.4%), suggesting that DFS use is not limited to household heads but extends across different social categories. Educational attainment was relatively high, with 50.0% holding a bachelor's degree, 44.9% having a master's degree or above, 2.6% completing technical and vocational training, and 1.9% having only a secondary education. This confirms that DFS adoption is strongly associated with higher levels of education, digital literacy, and exposure to modern banking systems. Regarding occupational status, 70.5% of the respondents were employed in government or private sectors, while smaller proportions were

self-employed, students, or unemployed. This finding suggests that employment — and by extension, regular income and financial stability — plays a role in encouraging DFS usage.

In terms of institutional affiliation, the majority of respondents (41.0%) accessed DFS through the Commercial Bank of Ethiopia (CBE), followed by Dashen Bank (27.6%). The other banks included Abyssinia, Awash, and *Nib* International Bank, albeit with lower representation. Notably, more than half of the respondents (57.7%) reported obtaining DFS from only one bank, suggesting limited multi-banking behaviors in the Ethiopian context. Furthermore, most of the respondents (93.6%) reported holding only savings accounts, with 94.2% using only deposit accounts, indicating that DFS adoption is still predominantly tied to basic savings products rather than more diversified financial portfolios.

Concerning the types of DFS, Automated Teller Machine (ATM) usage was the most common (91.7%), followed by mobile banking (64.5%), and utility bill payments (23.7%). Interestingly, 33.3% of the respondents reported using only one type of DFS, while 22.4% used two, and smaller proportions used multiple services. In terms of experience, 37% of the respondents had used DFS for one to three years, while 23.4% reported over 10 years of usage, suggesting a mixture of newer adopters and more experienced users in the sample.

In summary, these demographic findings illustrate that DFS adoption is concentrated among younger, educated, and employed individuals, with CBE and Dashen Bank dominating service provision. ATMs remain the entry point to DFS, though mobile banking is also growing steadily.

4.2.Major Findings

The study aimed to examine whether digital financial services — specifically card banking, mobile banking, and internet banking — enhance financial inclusion in Ethiopia from the demand-side perspective. To this end, binary logistic regression analysis was employed, complemented by evidence from semi-structured interviews with bank managers. The findings are organized along three analytical dimensions: access, quality, and usage.

i. Access Dimension: Accessibility and Innovation

Accessibility of DFS: Survey results show that DFS accessibility has improved significantly in Addis Ababa, where major banks have expanded ATM networks, POS terminals, and mobile banking platforms. Approximately 48.5% of the respondents either agreed or strongly agreed that

accessibility has positively contributed to financial inclusion, while 25.3% expressed disagreement. Regression results confirmed this perception: the odds ratio for "Accessibility" was Exp(B) = 179.3 with a p-value of 0.003, indicating that improved accessibility makes respondents 179 times more likely to be financially included. The interviews with bank managers reinforced these findings. One respondent noted that their bank operates over 500 branches, each equipped with POS machines, and provides mobile banking platforms to extend outreach. These accounts highlight that the expansion of DFS infrastructure directly correlates with inclusion outcomes.

This finding aligns with previous research. For example, Ozili (2018) argues that accessibility gaps remain a key barrier to DFS adoption globally, while Gujral and Kumar (2021) find that improved accessibility of mobile banking enhances inclusion in emerging economies.

Innovation in DFS: Innovation was also identified as a major driver of inclusion. Regression analysis revealed an odds ratio of Exp (B) = 22.9 (p = 0.028), confirming that innovation significantly enhances financial inclusion. Survey data show that 32.3% of the respondents agreed and 11.9% strongly agreed that innovation contributes positively, while 18.4% disagreed. Interviews with managers revealed that most banks have established IT wings dedicated to DFS innovation, though repair and maintenance are often outsourced to fintech providers. Respondents emphasized the need for improved infrastructure to maximize the benefits of new technologies. Innovations such as contactless payments and mobile money applications were cited as particularly transformative.

These results echo findings by Manta (2018), Shaikh *et al.* (2017), and Negussie (2020), all of whom show that DFS innovations promote financial inclusion, albeit at varying levels of significance depending on local contexts.

ii. Quality Dimension: Convenience, Trust, Performance, and Awareness

Convenience: Survey data showed that 82.1% of the respondents agreed that convenience influences inclusion, though regression results indicated an insignificant relationship Exp(B) = 7.9, p = 0.153). Interviewees confirmed that banks are making progress in improving convenience, for example, through shorter delivery times for debit cards and user-friendly platforms. However, persistent challenges such as ATM breakdowns, poor-quality cash notes, and network interruptions undermine user experiences. These findings are consistent with Makau

and Olando (2021), who observed a positive relationship between convenience and inclusion in Kenya, but with variations across income groups as noted by Ozili (2018).

Trust: Trust emerged as a highly significant factor. Regression analysis yielded Exp(B) = 391.5 (p = 0.004), suggesting that respondents who trust DFS are almost 400 times more likely to be financially included. While some managers highlighted INSA-certified security protocols, others pointed to rising fraud—particularly deception-based schemes that manipulate users—as a challenge to trust. This resonates with Ozili (2018), who argues that weak consumer protection erodes trust in DFS, thereby slowing inclusion. Similarly, Wu et al. (2013) highlight that trust strongly influences online banking adoption.

Performance: Performance was also found to be a significant predictor of financial inclusion. During interviews, bank managers agreed that high-quality digital financial services positively influence financial inclusion, especially during the COVID-19 pandemic when contactless services were most needed. One respondent noted that since most banks offer similar services, only superior digital performance and quality can drive meaningful inclusion. The survey results supported this view, with 68.1% of respondents agreeing to varying degrees, while 15.8% disagreed. Regression analysis further confirmed this, showing a significant effect of performance, with an odds ratio of 395.952 (p = 0.008). Overall, digital service quality and performance were found to strongly enhance financial inclusion in Ethiopia's banking industry. These results support studies by Khera *et al*. (2021) and Ye et al. (2022), which show that high-performance digital finance platforms reduce transaction costs, improve service delivery, and thereby enhance inclusion.

Awareness: Awareness was found to be both significant and influential, with regression results yielding Exp(B) = 105.2 (p = 0.003). Respondents largely agreed that awareness-raising strategies such as advertisements, incentives, and community campaigns positively influenced adoption. However, interviewees noted barriers such as voluntary exclusion (e.g., tax evasion or resistance from cash-dependent businesses). Prior research supports this finding, with Wyman (2017) and Shen et al. (2018) highlighting that financial literacy and awareness are crucial for increasing DFS uptake.

iii. Usage Dimension: Perceived Benefit of Usage

The perceived benefits of DFS were found to be critical in driving financial inclusion. Regression analysis confirmed a strong and significant relationship, with an odds ratio of Exp(B) = 134.0 (p = 0.004). A large proportion of respondents (67.4%) agreed or strongly agreed that perceived benefits influenced their decision to adopt DFS. This finding is further corroborated by the interview evidence. Bank managers emphasized that while DFS may not yet be highly profitable for banks, customers increasingly recognize its benefits in reducing transaction costs, saving time, and minimizing branch visits. The growing demand for credit cards and other digital services supports this trend. These findings are supported by studies such as Wu et al. (2013), Jain and Raman (2021), and Apramuka *et al.* (2020), all of which underscore that perceived usefulness, relative advantage, and risk–benefit perceptions are key determinants of digital finance adoption.

Table 1: Summary of logistic regression

Variable	Exp(B)	p-value	Effect
Accessibility (A)	179.270	0.003	Positive, Significant
Innovation (NI)	22.926	0.028	Positive, Significant
Convenience (C)	7.934	0.153	Positive, Insignificant
Perceived Benefit (PBU)	133.967	0.004	Positive, Significant
Trust (T)	391.518	0.004	Positive, Significant
Performance (P)	395.952	0.008	Positive, Significant
| Awareness (AW)	105.168	0.003	Positive, Significant

5. Conclusions and Recommendations

5.1.Summary of Key Findings and Conclusions

This study set out to examine whether digital financial services (DFS)—including card banking, mobile banking, and internet banking—enhance financial inclusion in Ethiopia from the demand-side perspective. Drawing on survey data from urban customers and supplemented with qualitative interviews with bank managers, the findings demonstrate that DFS adoption is indeed a critical driver of financial inclusion in the Ethiopian banking industry, though the effects vary across dimensions of access, quality, and usage.

On the access side, both accessibility and innovation emerged as significant determinants of financial inclusion. The expansion of ATMs, POS terminals, and mobile platforms has widened opportunities for previously excluded groups to participate in the financial system, while innovation in digital platforms has created more flexible and diverse entry points. These results

underscore the importance of continuous investment in infrastructure and technological development to extend outreach and reduce access barriers.

In terms of quality, trust, performance, and awareness were found to significantly enhance financial inclusion, while convenience, though positively related, showed no statistically significant effect. This suggests that users place greater value on the reliability, security, and efficiency of DFS than on convenience alone. Trust in particular proved to be central: without confidence in the safety of digital platforms, users are unlikely to engage meaningfully with DFS. Awareness campaigns and customer education also play a decisive role in promoting adoption, particularly among groups that may be hesitant or resistant to digital platforms.

From the usage perspective, the perceived benefits of DFS were found to strongly and significantly encourage adoption. Customers increasingly value DFS for its ability to reduce transaction costs, save time, and minimize physical branch visits, even as banks themselves continue to face challenges in profitability from these services. This highlights the dual role of DFS as both a tool for user empowerment and an emerging business model for financial institutions.

Overall, the findings reveal that DFS adoption in Ethiopia is expanding across demographic groups, contributing to greater participation in the financial system and gradually strengthening urban financial inclusion. However, the results also highlight persistent challenges, including infrastructural weaknesses, user trust concerns, and limited service diversification. Addressing these issues will be critical for translating the potential of DFS into sustained improvements in inclusive finance. In conclusion, digital financial services are not only transforming the way individuals interact with the banking system in Ethiopia but are also redefining the pathways toward financial inclusion. With supportive infrastructure, effective regulation, and innovative service design, DFS can serve as a cornerstone of Ethiopia’s financial inclusion agenda, particularly in urban areas where demand for digital solutions continues to rise.

5.2.Recommendations

The findings highlight several measures needed to strengthen the contribution of digital financial services (DFS) to financial inclusion in Ethiopia. Accordingly, several actions are recommended as follows.

- **Infrastructure**: The government should prioritize telecom and electricity expansion while enabling private investment in fintech infrastructure to improve access and reliability.
- **Inclusive design**: DFS platforms must be user-friendly and adaptable for the elderly, persons with disabilities, and less digitally literate populations to avoid exclusion.
- **Innovation capacity**: Banks should build in-house technical capacity and collaborate with fintechs to reduce reliance on external vendors and improve service continuity.
- **User experience**: Ethiopian banks should benchmark successful practices from countries like Kenya and Somalia to enhance convenience, interoperability, and agent networks.
- **Risk and trust**: Stronger fraud-prevention education, consumer protection mechanisms, and collaboration with INSA are vital for building user confidence.
- **Awareness:** Awareness campaigns using trusted community figures and networks can help reach financially excluded groups, particularly women and low-income households.
- **Service diversification**: Banks should expand beyond cards and mobile banking into e-wallets, online payments, and merchant services to meet diverse customer needs.
- **Regulatory support**: The National Bank of Ethiopia should strengthen oversight on interoperability, data protection, and balanced regulations that promote innovation while safeguarding users.

Finally, since this study focused only on the demand side of DFS, future research should integrate supply-side perspectives, include microfinance institutions, fintechs, and mobile money operators, adopt longitudinal designs to track changes over time, and consider factors such as financial literacy, cultural attitudes, and regulatory effectiveness.

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An Assessment of the Roles, Challenges, and Prospects of ICT Implementation in Private HEIs in Ethiopia: The Case of Unity and Admas Universities

Nigussie Teferi

Abstract

Despite its immense benefits, there are only a few studies made to assess the implementation of Information Communication Technology (ICT) in Ethiopian private higher education institutions (HEIs). This study assessed the roles, challenges, and prospects of ICT implementation at Unity and Admas Universities in Addis Ababa City. Using stratified proportionate sampling, 18 instructors and 372 students were obtained. A survey questionnaire and observation were employed to gather data. The data were analysed using descriptive statistics. Besides, a correlation test was used to review the relation between variables. Findings showed that ICT plays significant roles in enhancing active teaching-learning and in accessing course materials and promoting instructor-student interaction. Challenges were insufficient ICT infrastructures, the absence of technical support, and a low budget. Prospects included preparing learners for the practical world of work and offering opportunities to teach and learn regardless of geographical barriers. Based on the findings, suggestions to improve ICT infrastructure and to acquaint instructors, staff, and students with up-to-date innovations were given.

Keywords: Challenges, ICT implementation, private institutions, prospects, roles

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1. Introduction

1.1.Background

Information Communication Technology (ICT) is a diverse set of technological tools and resources to create, process, store, transmit, and share information using resources such as computers, telephones, the internet, networks, and other communication media. As ICT affects every economic, political, and social activity of human beings, it plays a crucial role in people's daily lives (Roztocki, 2019). Due to its multifaceted educational benefits, ICT has been applied in Higher Educational Institutions (HEIs) in developed and developing nations to enhance the quality of instruction. Habib and Ghulam (2017) explain that ICT is a very crucial resource in the 21st-century teaching-learning activity in HEIs.

The primary goal of both private and public HEIs is to deliver quality education, undertake robust research work, and maintain sufficient community service. HEIs are also places where ICT can be harnessed to meet goals and play significant roles in enhancing the quality of education, conducting applied research, and offering fruitful community service. As a recent phenomenon, ICT is also expected to bring about positive impacts directly or indirectly in all endeavours of HEIs (Eden, 2019). To mention a few of its direct impacts, for example, instructors can use ICT not only to deliver quality education but also to complement the instructional process using various technological applications.

Owing to ICT's abundant benefits, there is hardly any field of education where technology doesn't serve as a medium of instruction in HEIs. For instance, in private HEIs in Ethiopia, ICT is being used for video lectures, e-learning, and multimedia systems. In public HEIs, on the other hand, ICT is being used for simulations, telemedicine, video conferences, and for administering exit exams. Many more ICT tools are also being implemented as a medium of instruction in HEI classrooms around the globe. Besides, since the technology avoids communication gaps or barriers, applying ICT in HEI classrooms leads instructors and students towards making innovative research as well as providing community service.

In Ethiopia, private HEIs such as Unity University, St. Mary University, Admas University, and Rift Valley University, among others, are the vanguard institutions to implement ICT tools for various e-learning and e-library purposes. However, whether the ICT devices in use or the application mechanisms are up-to-date and sufficient remains a question. It is worth noting that both scarcity and lack of know-how about applying ICT bring forth overwhelming consequences on the educational process and the human output of the institutions. This is, therefore, one of the prime concerns that motivated the present researcher to undertake the current study.

Due to these and other problems related to the application of ICT in private HEIs, it was assumed that conducting a study would be beneficial, which would come up with possible solutions. To this end, the study was intended to assess what the roles, challenges, and prospects of ICT implementation in private HEIs look like. Hence, private HEIs, Unity University, and Admas University were taken from Addis Ababa City to conduct intensive assessments to propose solutions for the proper execution and utilization of ICT for educational purposes.

1.2. Statement of the Problem

Implementing ICT in private HEIs delivers multi-faceted support to instructors and students alike. However, its contribution remains underutilized for reasons such as a lack of short or long-term training, a shortage of ICT professionals, and communication network problems. Besides, insufficient numbers of computers, shortage of labs, unsuitable ICT use environment, lack of technical support, and shortage of technical support staff are visible problems. The study by Chirwa and Payal (2018) showed that most HEIs in developing countries are not supported by technology, and this has resulted in students' poor performance when compared to students of developed nations.

Possible causes of the problem could be the management and stakeholders of private HEI due to a lack of performing the roles required of them to bring and upkeep quality of education. Problems such as allocating insufficient budget and a lack of cooperation or delayed responses to provide solutions to hindering problems resulted in the application of the technology (Kingsley, 2017). Thus, using effective ICT needs an investigation into such challenges affecting the application of ICT in developing nations' HEIs, including Ethiopia's private HEIs.

Some studies are available abroad and in Ethiopia on applying ICT in public and private HEIs. For example, the study by Suresh & Sridevi (2019) in India found that ICT helps learn lessons in a more collaborative and interactive environment and provides unlimited resources. The study by Nour (2014) in Sudan found that using ICT enhances the creation and transfer of knowledge and increases the use of digital knowledge for academic and research purposes. In Ethiopia, Eden (2020) assessed the application of ICT in AAU and found that a lack of ICT infrastructure and shortages of teaching-learning aids were major challenges. Amanuel *et al*. (2022), who studied contributing factors to integrating ICT in Ethiopian HEIs, found that there were limited ICT resources, insufficient ICT infrastructure, a lack of skills, and resistance to change. This study differs in that it attempted to integrate roles, challenges, and prospects of applying ICT in a single study. Hence, the study aimed at assessing roles, challenges, and prospects of implementing ICT in private HEIs. To do this, the researcher conducted an intensive assessment at Unity and Admas Universities in Addis Ababa City. Therefore, to guide the study during its investigation, the following objectives and research questions were formulated.

1.3. Objectives of the Study

The study had the following objectives:

I. Assess the roles of implementing ICT for education in private HEIs.
II. Review challenges of implementing ICT for education in private HEIs, and
III. Explore prospects of implementing ICT for education in private HEIs.

1.4.Research Questions

The study intended to answer the following research questions:

I. What were the roles of implementing ICT for education in private HEIs?
II. What were the challenges of implementing ICT for education in private HEIs?
III. What were the prospects of implementing ICT for education in private HEIs?

1.5.Significance of the Study

The study is hoped to provide significant information to instructors, students, university administrators, policy makers, and researchers. First, the findings of this study are expected to inform teachers, students, and university administrators on the roles and values that ICT plays for education in HEIs. Results from the study are expected to show some ways to improve the application of ICT in private HEIs. It is also hoped to visualize some problem areas of ICT implementation to suggest solutions. Findings would help private HEIs to plan, design, and develop ICT policy and operational modes that support the educational process using technology. The results of the study could serve as inputs for concerned bodies to take action to improve the implementation of ICT in private HEIs. In addition, the results of the study might help other scholars to conduct further research on the use of ICT in public and private HEIs.

1.6. Scope and Limitations of the Study

Geographically, the study is delimited to only two private HEIs in Addis Ababa. Conceptually, this study was delimited to assess the roles, challenges, and prospects of implementing ICT for education in private HEIs. Finally, the time range for this study was delimited to a period of three academic years, i.e., 2020, 2021, and 2022 GC.

During the study, some of the major problems encountered were time constraints, lack of closely related reference materials, respondents' indifference to giving data, and budget constraints. Moreover, if the interview had been used to obtain qualitative data for in-depth results and

triangulation, it would have contributed much more to improving the results obtained in a better way.

2. Review of Related Literature

2.1.The Concept of ICT and its Development

ICT refers to the diverse sets of technological tools and resources used to communicate, create, disseminate, store, and manage information. As already indicated, it refers to forms of technologies that are used to create, store, share, transmit, and exchange information. This broad definition of ICT, according to Msila (2015), includes such technologies as radio, television, video, DVD, telephone (both fixed line and mobile phones), satellite systems, computer, and network hardware and software, as well as the equipment and services associated with these technologies, such as video conferencing and electronic mail.

Information can be defined as knowledge communicated by others or obtained from an investigation, study, or instruction. It could be a process by which the form of an object of knowledge is impressed upon by the apprehending mind to bring about a state of knowing (Eden, 2020). Technology, on the other hand, is the science of the application of knowledge to practical purposes. It determines the quality of life of people and the overall status of their nation. Information is the driving force of so many human activities in search of developing oneself, which has created a basis for the need to know (Chala & Yilfashewa, 2023).

To conclude, ICT has the potential to increase access to information; make learning available anytime and anywhere; and make learning more enjoyable for learners, thereby improving participation rates and learning outcomes. The use of ICT can also improve the quality of teaching, enable the creation of more relevant and stimulating learning materials, improve education management, enhance the provision of educational services, and make such services more cost-effective. In light of this, the rest of the review focuses on the roles, challenges, and prospects of implementing ICT.

2.2. Roles of ICT in Teaching and Learning

In the present globalized world, the roles ICT plays in every aspect of human life are tremendous. The same can be said about the role ICT plays in the teaching-learning process. Increasingly, ICT is being applied successfully in instruction, learning, and assessment. ICT is

considered a powerful tool for educational change and reform. Moreover, Fu (2013) says that ICT has the potential role of creating a new learning culture, making the teaching-learning process attractive and interactive, improving participation rates, and enhancing learning outcomes.

Musa and Tekapalli (2016) note that the use of ICT also improves the quality of teaching, enables the creation of more up-to-date and simulated learning materials, improves the skills of students and instructors, boosts the provision of educational services, and makes such services more cost-effective. Concerning the roles ICT plays in teaching-learning of HEIs, Brush, Glazewski, and Hew (2008) summarized them in five major points:

- Assist students in accessing digital information efficiently and effectively;
- Create opportunities for self-centered and self-directed learning;
- Provide a creative teaching-learning environment.
- Promote collaborative learning; and
- Support the teaching-learning process by facilitating access to courses.

2.3.ICT Infrastructures

As stated above, the term ICT refers to all forms of technology that are used to transmit, process, store, create, display, share, or exchange information by electronic means. Msila (2015) explains that the term ICT includes computers, the internet, and electronic delivery systems such as radios, televisions, and projectors, among others, and is widely used in today's education field. To this end, ICT infrastructure encompasses all the devices, networks, protocols, and procedures that are employed in information technology fields to foster interaction amongst various stakeholders. Nowadays, ICT infrastructure sectors are becoming more appropriate to help teach, learn, assess, and administer in schools. They enable schools to arrange for the strong use of digital technologies in their daily experiments.

According to Machunwangliu (2013), infrastructure consists of hardware (mainly physical servers), software, networks, data centres, facilities, and related equipment used to develop, test, operate, monitor, manage, and support ICT services. ICT infrastructures are all the setups and systems used in an organization. Key ICT infrastructures include hardware and software, physical stock previously invested in, and now available for utilization. Finally, ICT includes

computer hardware (servers and related workstations), network connectivity with accessories, and all necessary equipment.

2.4.Challenges of Using ICT in Teaching and Learning

Several studies have shown that the appropriate use of ICT can raise educational quality and connect learning to real-life situations (Hailye, 2019). As Msila (2015) has pointed out, learning is an ongoing lifelong activity where learners change their expectations by seeking knowledge, which departs from traditional approaches. As time goes by, they will have to expect and seek out new sources of knowledge. Skills in using ICT are an indispensable prerequisite for such learners. Chirwa (2018) says that challenges affecting ICT use in education or teaching-learning include inadequate ICT resources, poor technology skills by students, instructors, and ICT professionals, as well as communication network problems. Similarly, Payal (2018) lists the challenges as a lack of ICT infrastructures, insufficient computers, a shortage of laboratories, slow internet connection, unsuitable environment for ICT use, lack of support to educators and students, and lack of ICT support staff to aid students and instructors.

Challenges of ICT use become serious when it comes to developing countries. Kingsley (2017) states that most of the HEIs in developing countries are not supported by technology, and thus student performance is poor when compared to the developed world. The teaching-learning institutions are required to integrate and use ICT for better knowledge and skills of their students. At the same time, stakeholders are required to work seriously for the improvement of education by giving attention to the implementation of this technology in both public and private higher educational institutions.

Amha and Fenta (2015) note that various challenges of ICT utilization and implementation include inadequate computer training and certified teachers, poor funding, irregular power supply, cost of equipment, and lack of relevant software. Akpov *et al*. (2023) identified challenges such as limited technical skills that reduce access to ICT in the classroom, an insufficient number of academic advisors, a lack of timely feedback from instructors, and reduced interaction with peers and instructors. Solomon (2018) summarized ICT challenges, stating that there are clear indications from many countries that the supply of relevant and appropriate software is a major obstacle hindering the wider application of the computer, especially for teaching and learning in higher institutions.

2.5.Prospects of ICT Implementation

ICT-based education is seen as the dominant engine for improving productivity and providing business opportunities. It is a key factor in generating future employment. For instance, virtual or distance learning can help overcome the problems associated with geographical isolation and is invaluable for students in remote areas (Inyang-Abia, 2015). Moreover, ICT assists in reducing lecturers' workloads through its use for lesson preparation and worksheets, writing students' reports and individual education plans, collating and analysing students' attainment of information for target setting, and recording and analysing attendance and disciplinary information (Chala and Yilfashewa, 2023).

ICT can assist lecturers to develop their lectures, for instance, by using the internet. In the context of lecturers' development, e-learning can be used for both initial and continuing development through courses, workshops, and other activities. There are several global gateways of online resources to support lecturers' development (Hussien, 2018). Their portals are various and provide opportunities for users to ask questions, post materials, and submit assignments, the author added.

ICT can improve students' problem-solving skills, provide opportunities for student-constructed learning, increase students' collaboration in projects, increase mastery of vocational and workforce skills, increase the preparation of students for most careers and vocations, and improve the confidence and attitude of students (UNESCO, 2014). Applying ICT to the educational process provides additional prospects for students, instructors, and institutions as well.

3. Research Methodology

3.1.Research Design

In this study, a descriptive research design was used because such a research design provides a picture of any situation as it naturally occurs and makes a report on the observed situation as it exists (Koranteng, 2012). The assumption to use descriptive design was that it would help get a description of the current status of the application of ICT for the education process in the selected private HEIs, thereby examining their roles, challenges, and prospects.

3.2.Sampling Techniques

The target population for this study consisted of instructors and students from Unity University and Admas University. Both institutions run different study programs. While the number of students from undergraduate and postgraduate studies at Unity University was 11,075, the number of students from Admas University of similar studies was 5300. The total student population of the two HEIs, as of the 2022 academic year, was 16, 375. On the other hand, the number of instructors at Unity University was 551 while that of Admas University was 250. This brings the total instructor population of both universities to 801. In sum, when the total student and instructor population is reckoned, we find a total population size of 17, 176. Accordingly, to determine the sample size from the obtained instructor and student population, the sample size determining formula by Israel (1992) was employed as given below:

$$n = \frac{N}{1 + N(e)}$$

Where n – designates the sample size the research uses;

- N - designates the total number of the target population;
- e – designates maximum variability or margin of error 5% (0.05), and
- 1 – designates the probability of the event occurring.

Thus, the sample size was obtained as:

$$N = \frac{17,176}{1 + 17,176\ (0.05)^2} = 390$$

Because instructors and students for the study came from different HEIs and programs with unequal total populations, a proportional stratified sampling technique was employed. Hence, first, participants were categorized into two strata, consisting of each HEI and each program of study, to obtain a sample size of 390, as calculated by Israel (1992), and as given in Table 1.

Table 1: Population, sampling technique, and sample size

Study Site	Program	Population Size		Sampling Technique	Sample Size	
1. Unity University	Undergraduate	Students	10, 120	Stratified random	Students	230
	Postgraduate	Students	955	Stratified random	Students	22
	UG & PG	Instructors	551	Stratified random	Instructors	12

	Total Population		**11, 626**	**Total Sample**		**264**
2. Admas University	Undergraduate	Students	5, 000	Stratified random	Students	114
	Postgraduate	Students	300	Stratified random	Students	6
	UG & PG	Instructors	250	Stratified random	Instructors	6
	Total Population		**5, 550**	**Total Sample**		**126**
1. Unity University population total			11, 626	1. Unity University sample total		264
2. Admas University population total			5, 550	2. Admas University sample total		126
Population Grand Total			17, 176	Sample Grand Total		390

3.3.Instruments

Data for the study were gathered from primary and secondary sources. Primary data were collected from sample students and instructors. Two types of instruments were used for data collection, namely a structured questionnaire and an observation checklist (or resource analysis). In such a way, two sets of questionnaires: one for students and another one for instructors, were prepared in line with the objectives, research questions, and the review of literature. Both questionnaires had four parts, and the first part dealt with questions on respondents' demography, while the remaining parts (Part Two, Three, and Four) were on the Roles, Challenges, and Prospects of implementing ICT, respectively. They were designed to address the research questions and objectives. On the other hand, for resource analysis, a semi-structured checklist was prepared to collect data on the existing ICT resources and their uses for the teaching-learning process. To discuss the responses to the questionnaire, the value of each variable was defined by using class width intervals (Lind, Marchal, Wathon, 2015) as follows. The interval width of each level = the highest score – the lowest score, interval number = 5 - 1/5 = 0.80. Therefore, the result of the data analysis regarding each variable was defined using this classification: Strongly Agree = 5, Agree = 4, Neutral = 3, Disagree = 2, and Strongly Disagree = 1. The details of each class interval width are given in Table 2.

Table 2: Width of Likert-scale class interval

Strongly Agree (5)	**Agree(4)**	**Neutral (3)**	**Disagree (2)**	**Strongly Disagree(1)**
5.00 - 4.21	4.20 - 3.41	3.40 - 2.61	2.60 - 1.81	1.80 - 1.00

3.4.Data Collection Procedures

Before the survey questionnaires were distributed, the letter for cooperation was handed to each campus dean of the two Universities. Then, the questionnaires prepared for instructors and students were distributed to the sampled participants, together with the department heads of both

institutions. The researcher himself collected the responses from instructors and students an hour and a half later than the distribution period. Also, the observation checklist was filled out by going to the respective infrastructure, including classrooms, computer labs, and each network facility, to ensure the availability and functionality of ICT infrastructure in the institutions. The observation was carried out with the help of staff members of each institution.

3.5.Reliability of Instrument

The reliability of measuring instruments answers the question of when the results of the measuring processes are consistent; on occasion, they should be consistent. Reliability, as a statistical concept, is related to consistency and dependability in obtaining the same relative answer when measuring phenomena that have not changed (Burns and Bush, 2010). Although various methods exist, Cronbach Alpha was chosen as a suitable measure to assess the internal consistency of instruments in the research, where the value of Cronbach Alpha above .70 is acceptable reliability, and values of 0.60 to 0.70 are lower for acceptability, and those greater than 0.80 and 0.90 are good and excellent, respectively (Zikmund *et al*. 2010).

Table 3: Cronbach alpha coefficients for internal consistency of scales

SN	Variables	Questionnaire Type			
		Students		Teachers	
		Items	Cronbach Alpha	Items	Cronbach Alpha
1.	Roles of implementing ICT for education,	8	.718	8	.765
2.	Challenges of implementing ICT for education,	8	.771	9	.782
3.	Prospects of implementing ICT for education,	8	.767	7	.769

Table 3 presents Cronbach's Alpha test results for three items of student and teacher questionnaire items on roles, challenges, and prospects of implementing ICT. In each case, the result was quite over the recommended $\alpha = .70$ threshold (Pallant, 2007). So, the results of the measurement scales revealed that the Cronbach alpha values are reasonably high for each variable.

3.6.Data Analysis Tools

Data from questionnaires were cleaned and coded, but the observation checklists were reviewed to verify the data. Questionnaire data were fed into SPSS software, and output was organized,

tabulated, and described quantitatively, using frequency, percentage, mean, and standard deviation. However, data from the observation checklist were analysed and described using the qualitative method. Besides, a Pearson Correlation Test was carried out to review the existing relationship between the dependent variable (implementation of ICT) and the independent variables (roles, challenges, and opportunities). Finally, the results of the data from both instruments were brought together to show the findings of the study.

4. Results and Discussion

A total of 390 copies, 18 copies of questionnaires for instructors, and 372 copies of questionnaires for students were administered. Since all 390 copies of the survey instruments were filled out and returned, it is possible to conclude that the response rate was 100%.

Table 4: Data from questionnaires on respondents' demography

Instructors Demographic Data			**Students Demographic Data**		
Variables	Response in Fr. & %		Variables	Responses in Fr. & %	
1. Instructors' faculty/department?	**Fr.**	**%**	**1. Students' field of study?**	**Fr.**	**%**
A. COSC	2	11.1	A. COSC	40	10.8
B. FBE	11	61.2	B. FBE	301	80.9
C. Engineering	3	16.7	C. Engineering	21	5.6
D. Health Science	1	5.5	D. Health Science	6	1.6
E. Sociology	1	5.5	E. Sociology	3	0.8
F. Leadership	-	-	F. Leadership	1	0.3
Total	**18**	**100**	**Total**	**372**	**100**
2. Instructors' level of study	**Fr.**	**%**	**2. Students' program of study**	**Fr.**	**%**
A. BA / BSc	3	16.7	A. BA / BSc	344	92.5
B. MA / MSc	14	77.8	B. MA / MSc	28	7.5
C. PhD	1	5.5	C. PhD	-	-
Total	**18**	**100**	**Total**	**372**	**100**
3. Instructors' service year	**Fr.**	**%**	**1. Students' year of study**	**Fr.**	**%**
A. 1 to 4 years	4	22.2	A. 1st year	-	-
B. 5 to 9 years	4	22.2	B. 2nd year	113	30.4
C. 10 to 14 years	3	16.7	C. 3rd year	88	23.6

D. 15 and above years	7	38.9	D. 4th year	163	43.8
Total	**18**	**100**	**E. 5th year**	**8**	**2.2**
2. Instructors' present duty/work?	**Fr.**	**%**	**Total**	**372**	**100%**
A. Instructor	12	66.7			
B. Department Head	4	22.2			
C. University Higher Official	2	11.1			
D. Coordinator	-	-			
Total	18	100			

As illustrated in Table 4, demographic data point out that respondents showed more homogeneous characteristics as they were from similar fields of study, such as COSC, FBE, Engineering, Health Science, and Social Science, as well as two study levels and programs-undergraduate and post-graduate. Besides, both groups of respondents had a modest amount of teaching and learning experience, in that 7 (38.9%) of teachers had ≥15 years of experience, while 163 (43.8%) students had 4 years of experience in HEIs. In sum, the demographic information showed that study participants represented all fields and programs of study and that they had sufficient experience in teaching and learning. This would possibly indicate that the data they provided could be reliable and trustworthy. The following discussion focuses on the results of the data analysis based on three research questions formulated earlier in part one.

Research Question 1 asked, *'What were the roles of implementing ICT for education in private HEIs?'* To review what roles implementing ICT played in teaching-learning and to answer the research question, students were asked eight items as given in Table 5.

Table 5: Data from the student questionnaire on roles of ICT implementation

SN	Implementing ICT for Teaching and Learning	SA		A		N		DA		SDA		N	M	SD
		Fr.	%	Fr.	%	Fr.	%	Fr.	%	Fr.	%			
1.	Motivates engagement in active learning	165	44.4	161	43.3	2	.5	39	10.5	5	1.3	372	4.19	.978
2.	Assists in the exchange of educational information	167	44.9	170	45.7	3	.8	27	7.3	5	1.3	372	4.26	.897

3.	Helps access course materials	181	48.7	133	35.8	1	.3	43	11.6	14	3.8	372	4.14	1.129
4.	Assists slow students to learn at their own pace	197	53.0	138	37.1	-	-	22	5.9	15	4.0	372	4.29	1.024
5.	Helps improve practical skills	180	48.4	147	39.5	2	.5	33	8.9	10	2.7	372	4.22	1.020
6.	Replaces teacher-centred with Student-centred learning	189	50.8	126	33.9	3	.8	26	7.0	28	7.5	372	4.13	1.208
7.	Supports learning by using various instructional media	176	47.3	143	38.4	-	-	42	11.3	11	3.0	372	4.16	1.081
8.	Promotes collaboration during the lesson	203	54.6	115	30.9	1	.3	39	10.5	14	3.8	372	4.22	1.123
		Overall Mean (SD)= 4.20(.491)												

Note: SA= Strongly Agree, A= Agree, N= Neutral, DA= Disagree, SDA= Strongly Disagree, M= Mean, and SD = Std. Deviation.

The results in Table 5 showed overall M= 4.20 and SD=.491 values, implying that all respondents agreed to the eight questions asked about the roles of implementing ICT for the education process. When the mean value falls between 4.20 and 3.41, it shows agreement, proving that implementing ICT for the teaching-learning process played a significant and useful role.

Table 6: Data from instructors' questionnaire on roles of ICT implementation

SN	**Implementing ICT for Teaching and Learning**	**SA**		**A**		**N**		**DA**		**SDA**		**N**	**M**	**SD**
		Fr.	**%**	**Fr.**	**%**	**Fr.**	**%**	**Fr.**	**%**	**Fr.**	**%**			
1.	Helps instructors engage students in active learning	7	38.9	9	50.0	-	-	2	11.1	-	-	18	4.17	.924
2.	Assists instructors improve practical skills of technology	8	44.4	8	44.4	-	-	2	11.1	-	-	18	4.22	.943
3.	Helps collaboration among instructors for better teaching	7	38.9	10	55.6	-	-	1	5.6	-	-	18	4.28	.752
4.	Provides instructors with access to sufficient course materials	7	38.9	10	55.6	-	-	1	5.6	-	-	18	4.28	.752

5.	Helps instructors prepare up-to-date teaching materials	8	44.4	9	50.0	-	-	1	5.6	-	-	18	4.33	.767
6.	Gives a chance to teach courses using various media	9	50.0	7	38.9	-	-	2	11.1	-	-	18	4.28	.958
7.	Helps teach without moving to the classrooms	8	44.4	9	50.0	-	-	1	5.6	-	-	18	4.33	.767
8.	Enables instructors to give project activities as an assignment	5	27.8	11	61.1	1	5.6	1	5.6	-	-	18	4.11	.758
Overall Mean (SD) = 4.25 (.580)														

In Table 6, similar to students, instructors were asked eight questions to review what roles ICT for education would play. As a result, with an overall mean value of M=4.25 and SD=.580, the respondents agreed to all eight questions. Since the mean value obtained was greater than 4.20, it indicated that respondents strongly agreed with all the questions asked. Based on the result of the stated outcome, it was feasible to conclude that applying ICT for education provides several useful roles.

Finally, as per the attempt made to answer Research Question 1*: 'What were the roles of implementing ICT for education in private HEIs?'* The data analysis on instructor and student results showed that implementing ICT for the teaching-learning process plays various roles: motivating students to be engaged in active learning, promoting ease of access to course materials, assisting students and instructors to improve their practical technology skills, creating opportunities to teach and learn courses using various instructional media, promoting collaboration to teach and learn the lesson, and replacing teacher-centred methodology by student-centred one.

Regarding Research Question 2*, 'What were the challenges of implementing ICT for education in private HEIs?* Student and instructor respondents were asked eight and nine questions, respectively, regarding the challenges of using ICT for teaching-learning. The data from the two sources are discussed in Tables 7 and 8.

Table 7: Data from student questionnaire on challenges of ICT implementation

SN	**Challenges of ICT Implementation**	**SA**		**A**		**N**		**DA**		**SDA**		**N**	**M**	**SD**
		Fr.	**%**	**Fr.**	**%**	**Fr.**	**%**	**Fr.**	**%**	**Fr.**	**%**			

1.	1. Students limited to ICT practical skills	130	34.9	190	51.1	3	.8	43	11.6	6	1.6	372	4.06	.982
2.	2. Students' misuse of ICT for an inappropriate purpose	65	17.5	37	9.9	-	-	151	40.6	119	32.0	372	2.40	1.461
3.	3. Instructors' limited ICT practical skills	185	49.7	132	35.5	1	.3	40	10.8	14	3.8	372	4.17	1.116
4.	4. Lack of instructor motivation to use ICT for teaching	165	44.4	176	47.3	-	-	25	6.7	6	1.6	372	4.26	.890
5.	5. Absence of technical support during teaching learning	127	34.1	198	53.2	2	.5	36	9.7	9	2.4	372	4.07	.974
6.	6. Insufficient ICT infrastructure in HEIs	184	49.5	166	44.6	1	.3	15	4.0	6	1.6	372	4.36	.821
7.	7. Lack of a suitable environment for ICT use in institutions	190	51.1	148	39.8	-	-	27	7.3	7	1.9	372	4.31	.937
8.	8. Presence of a large class to use available ICT resources	139	37.4	188	50.5	1	.3	36	9.7	8	2.2	372	4.11	.973
		Overall Mean (SD) = 4.22(.406)												

According to Table 7, students were asked eight questions about the challenges of implementing ICT for education. First, the majority of the students indicated agreement with seven of the eight questions, where the overall mean value of responses became M=4.22 and SD=.406. Based on the obtained mean, which falls between 5.00 and 4.21, it could be concluded that respondents strongly agreed. This showed, therefore, that implementing ICT for teaching and learning did have challenges as listed in the same table.

Similarly, instructors were asked nine questions to review whether they would agree or disagree with some projected challenges of implementing ICT for education (Table 8). As a result, with an overall mean value of M=4.45 and SD =.254, respondents showed agreement with all of the nine questions. Hence, the challenges listed in Table 8 could be accepted as they existed in each private institution because the mean value falls within the class range for agreement. In sum, in line with the discussion held on challenges of ICT application, as all responses from the instructor and student respondents showed similar agreement, the listed challenges could be taken as they existed in the institutions. These included a lack of technical support during the teaching-learning process, insufficient ICT infrastructure in addition to the existing poor internet

connection, large class sizes, a lack of a suitable environment for ICT use, absence of support from the management body, and low budget allocation to implement ICT. Besides, as data from resource observation confirmed, there is a poor internet connection, insufficient computer labs, limited practical skills of ICT support staff, a lack of ICT use in classrooms (LCD projector, computer, and network accessibility), and the institutions' websites and e-mail services are less functional.

Table 8: Data from instructors' questionnaire on challenges of ICT implementation

SN	Challenges of ICT Implementation	SA		A		N		DA		SDA		N	M	SD
		Fr.	%	Fr.	%	Fr.	%	Fr.	%	Fr.	%			
1.	Instructors' limited ICT skills	6	33.2	10	55.6	1	5.6	1	5.6	-	-	18	4.17	.786
2.	Lack of motivation to implement ICT for teaching	9	50.0	8	44.4	-	-	1	5.6	-	-	18	4.39	.778
3.	Lack of technical assistance from ICT support staff	10	55.6	7	38.8	-	-	1	5.6	-	-	18	4.44	.784
4.	Less management support for ICT implementation	13	72.2	4	22.2	-	-	1	5.6	-	-	18	4.61	.778
5.	Poor budget allocation for ICT implementation	13	72.2	4	22.2	-	-	1	5.6	-	-	18	4.61	.778
6.	Lack of instructor training to update on ICT findings	9	50.0	8	44.4	-	-	1	5.6	-	-	18	4.39	.778
7.	Lack of sufficient ICT infrastructure	11	61.1	6	33.3	-	-	1	5.6	-	-	18	4.50	.786
8.	Poor internet connection	10	55.6	8	44.4	-	-	-	-	-	-	18	4.56	.511
9.	Large student class size for ICT resource utilization	9	50.0	8	44.4	-	-	1	5.6	-	-	18	4.39	.778
		Overall Mean (SD) = 4.45 (.254)												

In response to the third Research Question*, 'What were the prospects of implementing ICT for education in private HEIs?*', the findings are depicted in Tables 9 and 10.

Table 9: Data from the student questionnaire on prospects of ICT implementation

SN	Prospects of Implementing	SA	A	N	DA	SDA	N	M	SD

	ICT	Fr.	%	Fr.	%	Fr.	%	Fr.	%	Fr.	%			
1.	Enables students to relate academics to practical work	189	50.8	154	41.4	1	.3	25	6.7	3	.8	372	4.35	.857
2.	Trains for a future career	227	61.1	121	32.5	-	-	18	4.8	6	1.6	372	4.47	.857
3.	Helps produce a technologically literate workforce	89	23.9	233	62.6	3	.8	37	9.9	10	2.7	372	3.95	.942
4.	Helps adapt to future emerging technology	134	36.1	186	50.0	2	.5	38	10.2	12	3.2	372	4.05	1.032
5.	Produces students who solve problems by doing research	327	87.9	28	7.5	1	.3	6	1.6	10	2.7	372	4.76	.779
6.	Strengthens teaching by giving the chance to communicate with students from the outside world	110	29.6	232	62.4	2	.5	16	4.3	12	3.2	372	4.11	.868
7.	Provides the chance to learn anywhere, regardless of geographical boundary	151	40.6	178	47.8	1	.3	26	7.0	16	4.3	372	4.13	1.030
8.	Ensures educational equity for disabled learners	55	15.1	48	12.9	-	-	139	37.4	129	37.4	372	2.36	1.579
		Overall Mean(SD) = 4.09 (.434)												

To answer this research question and to review the prospects of using ICT in teaching-learning processes, students were first asked eight questions. As indicated in Table 9, when the overall mean values of responses to these eight questions were calculated, the result became M=4.09 and SD=.434. So, when the mean values fall between 4.20 and 3.41, it indicates agreement. Consequently, it was possible to suggest that implementing ICT for teaching-learning did have various prospects for students, as the lists of items indicated in the same table.

Table 10: Data from the instructor questionnaire on prospects of ICT implementation

SN	Prospects of Implementing ICT	SA		A		N		DA		SDA		N	M	SD
		Fr.	%		Fr.	%		Fr.	%		Fr.			
1.	Helps adapt to future emerging technologies	14	77.8	4	22.2	-	-	-	-	-	-	18	4.17	1.249

2.	Helps instructors to get up-to-date knowledge of the subject area	12	66.7	5	27.8	-	-	1	5.6	-	-	18	4.61	.502
3.	Enables students to produce students who relate academics to the practical world of work	9	50.0	8	44.4	-	-	1	5.6	-	-	18	4.00	1.029
4.	Assists in the development of a career with online training	8	44.4	9	50.0	-	-	1	5.6	-	-	18	4.11	.900
5.	Helps get the capacity to perform in a borderless knowledge-based economy	2	11.1	2	11.1	1	1.56	7	38.9	6	33.3	18	2.28	1.364
6.	Promotes involvement in research to improve teaching	10	55.6	7	38.9	-	-	1	5.6	-	-	18	3.83	1.249
7.	Strengthens teaching, giving a chance to communicate with instructors from the outside world	2	11.1	3	16.7	-	-	7	38.9	6	33.3	18	2.33	1.414
		Overall Mean (SD) = 4.49(.291)												

As given in Table 10, instructors were asked seven questions to review the results of applying ICT. Since the responses that instructors gave to these seven questions had an overall mean value of M=4.49 and SD =.291, it also indicated agreement. So, it could be inferred that using ICT for education would bring various opportunities as listed in the table. To wrap up, as indicated in Tables 9 and 10, both groups of respondents agreed on several points. These included the potential prospects that employing ICT for education brings, such as: helping students and instructors to adapt to new emerging technologies, creating students who solve problems through research, improving teaching-learning by offering learners opportunities to interact with students from the outside world, preparing them for a future career, and supporting instructors in acquiring knowledge on recent technologies.

The Pearson correlation coefficient test was employed to review the strength, direction, and relation between the mean result of independent variables (roles, challenges, and opportunities) and that of the mean result of the dependent variable (ICT implementation) for both instructors and students. The results are given in Tables 11 and 12.

Table 11: Correlation coefficient test results for instructors

Independent Variables Instructors' Data		**Dependent Variable**	
		Mean ICT Implementation	
Mean: Role of ICT Implementation	Pearson's correlation Sig. (2-tailed) N	1 18	-.482* .043 18
Mean: The Challenge of ICT Implementation	Pearson's correlation Sig. (2-tailed) N	-.482* .043 18	1 18

NB: Correlation is significant at the 0.01 level (2-tailed).

In Table 11, the correlation test on instructor data results reveals a significant correlation between the independent variables (roles and challenges) and the dependent variable (ICT implementation) with the value of (r=**-.**482*, p <.05). This result shows that the more ICT is implemented for teaching-learning, the more challenges may occur during implementation.

Table 12: Correlation coefficient test results for students

Independent Variables students' data		**Dependent Variable**	
		Mean ICT Implementation	
Mean: Roles of ICT Implementation	Pearson's Correlation Sig. (2-tailed) N	1 372	.195** .000 372
Mean: Prospects of ICT Implementation	Pearson's Correlation Sig. (2-tailed) N	.195** .000 372	1 372

NB: Correlation is significant at the 0.01 level (2-tailed)

Similarly, in Table 12, the correlation test result on students' data shows the relation between the independent variables (roles and prospects) and the dependent variable. ICT implementation was significantly positively correlated with the level of significance (r=.195**, p< .01 level). This result shows that the more ICT is implemented, the more roles it plays in improving teaching-learning, and the more prospects it brings to subjects.

5. Conclusions and Recommendations

5.1.Conclusions

The current study assessed the roles, challenges, and prospects of implementing ICT for the educational process. The prevalence of appropriate teaching-learning processes is closely related to the application of ICT. Additionally, to implement ICT for education, the quality and quantity of ICT infrastructure should be given due attention. The study points out that roles and prospects of ICT application are likely to improve when some or all of the challenges are addressed

(Hvorecky and Cesta, 2005). With these assumptions in mind, the researcher collected data from 18 instructors and 372 students at two private HEIs in Addis Ababa. In addition, data were gathered using a resource and service observation checklist. To examine the impact and relation between the independent and dependent variables, the data were analysed using descriptive statistics and the Pearson correlation coefficient test.

The findings showed that implementing ICT for education plays an important role in supporting instructors and students, in improving and making the lessons appealing and participatory. The findings also revealed that using ICT has promising prospects for students, instructors, and institutions since it significantly improves teaching-learning, technical skills, and collaboration of students and instructors alike. Challenges of applying ICT include poor ICT infrastructure and services, lack of training, and inadequate budget allocations.

5.2.Recommendations

As the findings indicate, the major problems in the two private HEIs studied were inadequate allocation of budget, lack of teacher training, poor internet connection, shortage of ICT infrastructure, and lack of technical support. Consequently, to maintain the teaching and learning process better than the present, top management, administration, and concerned bodies are advised to consider the following suggestions.

i) Increasing the amount of budget to the level they could to maintain training venues for instructors so that they could be familiar with the ever-changing ICT innovations;

ii) Enhancing the budget can also mitigate poor internet connection observed in the institutions, because it is when the internet connection is reliable that instructors and students access course materials and other ICT resources as desired.

iii) Devising ways to maintain technical support staff and/or, in the case where there is a shortage, recruiting support staff to assist with technical issues and work in labs;

iv) As capacity permits, taking step-by-step measures to fulfil ICT infrastructure, and update/upgrade existing resources and services to the current level of technology is indispensable.

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Prediction of Undrained Shear Strength Using Artificial Neural Network-Based Model: The Case of Bole Arabsa Site, Addis Ababa

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Abstract

Numerous local studies have focused on correlation analyses using traditional methods, but these methods often rely on simplified assumptions and struggle with noisy or missing data. In contrast, Artificial Neural Networks (ANNs) offer a more advanced approach by accommodating multiple nonlinear variables and effectively generalizing complex interactions. Unlike conventional regression models, which handle only a single response, ANNs can process multiple outputs simultaneously. This study aims to predict the undrained shear strength (Cu) of fine-grained soils using an ANN-based model, demonstrating its superior accuracy compared to empirical methods. By incorporating data from Standard Penetration Tests, Liquid Limits, and Plasticity Indices, ANNs are shown to be particularly effective in modeling the complex relationships in fine-grained soils. The performance of the ANN model was evaluated using the correlation coefficient (R^2) and root mean square error (RMSE), showing that the ANN model performs better than traditional multiple regression analysis (MRA). For silty clay soils, the ANN model, which relates Cu with SPT, PI, and LL using a tansig-purlin transfer function, achieved a high R^2 value of 0.956, indicating strong predictive accuracy. A comparison between the ANN model and regression analysis showed R^2 values of 0.9659 for the ANN and 0.8819 for the regression, further proving the superior performance of the ANN. Overall, this study confirms that ANN models are a faster and more cost-effective alternative to conventional laboratory methods for predicting undrained shear strength.

Keywords: Artificial neural network, undrained shear strength, index property, and standard penetration test

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1. Introduction

1.1.Background

Ensuring the stability and safety of structures relies heavily on a deep understanding of the soil's engineering properties. However, obtaining these properties through conventional means often requires significant time and financial investment. Several methods, including field and laboratory tests, have been developed to assess soil properties. Laboratory methods such as the triaxial and unconfined compression tests are critical for determining the undrained shear

strength of soils. In large-scale construction projects, where time and resources are limited, empirical correlations play a vital role in predicting geotechnical parameters from simpler, readily available test results. These correlations, particularly those between index properties, Standard Penetration Test (SPT) data, and laboratory results for fine-grained soils, facilitate easier prediction of undrained shear strength. Recent studies have shown that Artificial Neural Networks (ANNs) provide even more accurate predictions than traditional empirical methods.

The introduction of Artificial Intelligence (AI) into geotechnical engineering has revolutionized the field by enhancing predictive capabilities and providing deeper insights that conventional approaches sometimes fail to deliver (Elshorbagy *et al.* 2010). ANNs, in particular, are mathematical models inspired by the structure and functionality of biological neural networks (Haryana, 2017). These models mimic the learning and problem-solving capabilities of the human brain (Anderson & McNeill, 1992), which is an intricate natural neural network underlying cognitive functions such as reasoning and decision-making (Wasserman, 1989).

Several empirical correlations have been established between the SPT N-value and various engineering properties of soil, including unconfined compressive strength (qu). SPT is particularly useful when projects face financial or time constraints, or when obtaining undisturbed soil samples is difficult (Jibahand, 2017). To estimate the undrained shear strength of fine-grained soils, parameters such as natural water content (wn), liquid limit (LL), and plasticity index (PI) are used alongside the SPT N-value (Nassaji *et al.* 2011).

Since determining index properties is generally quicker and less costly than investigating other engineering properties, many engineering characteristics can be predicted through empirical correlations based on these index properties. Thus, by using simpler testing methods to obtain soil index properties, it is possible to make reliable predictions of engineering properties without extensive time and effort.

This study aims to develop a neural network model to predict the undrained shear strength of cohesive soils found in Bole Arabsa, utilizing ANN techniques to provide a quicker and more cost-effective alternative to conventional laboratory tests. By gathering data from geotechnical investigation reports conducted by the Addis Ababa Housing Construction Office, the study seeks to ensure high-quality and realistic results. After completing the prediction, the

performance of the ANN model will be evaluated against previously developed models in other regions to assess its effectiveness in estimating unconfined compressive strength. Ultimately, this research presents a novel approach to calculating undrained shear strength, highlighting the advantages of ANN-based algorithms in geotechnical analysis.

1.2.Statement of the Problem

Several local studies have focused on developing correlations using conventional methods. However, these traditional approaches are limited by their reliance on simplified assumptions, such as the presumption of linear behavior, and they are less effective in dealing with noisy or incomplete data. They also struggle to accommodate multiple nonlinear variables and unknown interactions. In contrast, Neural Network (NN) models offer several advantages, including universal function approximation capabilities, resistance to noisy or missing data, and the ability to manage complex, nonlinear variables. These features give NN models a superior generalization capability compared to conventional methods.

This study aims to develop a neural network model specifically designed to predict the undrained shear strength of fine-grained soils. The goal is to provide an efficient and cost-effective alternative to traditional laboratory tests, enabling quicker predictions with reduced financial input. By leveraging the power of neural networks, the study seeks to demonstrate that this model can streamline the prediction process while maintaining accuracy, making it particularly valuable in large-scale projects where time and budget constraints are critical.

1.3.Objectives of the Study

The study had the following general and specific objectives:

i) General Objective

The primary objective of this study was to predict the undrained shear strength of fine-grained soils in Bole Arabsa using an artificial neural network-based model.

ii) Specific Objective

Specifically, this study had two major objectives:

- Demonstrate that the predictions made using the ANN model yield superior results compared to traditional empirical methods.

- Identify the index properties that enhance the prediction performance for undrained shear strength.

2. Review of Related Literature

2.1. Introduction

In geotechnical engineering, estimating parameters from in-situ test data is often essential. One such critical parameter is undrained shear strength (Cu), which is widely used to assess bearing capacity and soil stability. Since laboratory tests to determine Cu can be expensive and time-consuming, empirical formulas and alternative methods provide efficient and cost-effective solutions for these assessments.

2.2. Index Property and SPT-N

Due to the wide variety of natural soils and the complexity involved in detailed soil testing, engineers often rely on simplified tests to gain quick insights into soil properties. These simplified tests are known as index properties. They provide useful indicators of soil behavior and are commonly used to guide preliminary design and assessment.

The Atterberg limits are typically determined for the soil fraction passing through a 425-micron sieve. This is because the Atterberg limits primarily assess the behavior of cohesive soils, specifically clays and silts, which are most responsive to changes in moisture content. Here is a detailed look at the implications of this approach (Murthy, 2002).

$$\text{Modified liquid limit (WLL)} = LL \times F/100 \quad (1)$$

$$\text{Modified plasticity index (WPI)} = PL \times F/100 \quad (2)$$

Where F is the fraction passing through 425 microns

The Standard Penetration Test (SPT) is among the simplest, most cost-effective, and widely used tests in geotechnical projects globally (Sirvikaya, 2009). Research has demonstrated the effectiveness of SPT in estimating the undrained shear strength of fine-grained soils in southern and eastern Tehran, Iran, utilizing multiple linear regression analysis via SPSS software. This investigation was conducted in two phases: the first phase considered only the SPT number (N) as the independent variable, while the second phase incorporated additional parameters, including natural water content (wn), liquid limit (LL), and plasticity index (PI), alongside N (Nassaji et al., 2011).

The SPT N-values/300mm should be adjusted for different factors before employing them for computing the allowable bearing pressure. The SPT N-values are converted to the N'70 standard energy ratio value (Bowles, 1988). The correlation value of SPT-N can be represented as follows:

$$N'_{70} = C_N * N * n_1 * n_2 * n_3 * n_4 \quad (3)$$

$N'_{70} = adjusted\ N,\ \ C_N = adjustment\ for\ overburden\ pressure(\sqrt{\frac{P''_o}{P'_o}})$

$$P'_o = overburden\ pressure$$

$P''_o = reference\ overburden\ pressure\ (95.76kPa\ or\ 1.0kg/cm2)$

$n_1 = \frac{E_r}{E_{rb}}$ (Where, Er is the average energy ratio that depends on the drill system, and Erb is the standard energy ratio);

$n_2 =$ Rod length correction;

For Rod length > 10 m, $n_2 = 1$, Rod length 6 - 10 m, $n_2 = 0.95$, Rod length 4 - 6 m, $n_2 = 0.85$ & Rod length 0 - 4 m, $n_2 = 0.75$

$$n_3 = sampler\ correction\ (1.00\ in\ this\ case),$$

$n_4 = borehole\ diameter\ correction\ (1.00\ in\ this\ case)$

2.3.Artificial Neural Network

Artificial Neural Networks have advantages in modeling complex geotechnical engineering problems. It offers significant benefits, especially in the context of materials with high variability and non-linear relationships such as those encountered in geotechnical engineering (Shahin & Maier, 2008).

Developing NN process models means that they do not depend on simplified assumptions such as linear behavior or production heuristics. Neural networks possess a number of attractive properties for modeling a complex mechanical behavior or a system: universal function approximation capability, resistance to noisy or missing data, accommodation of multiple

nonlinear variables for unknown interactions, and good generalization capability (Park, 2011). Determining the optimal architecture for an Artificial Neural Network can be a complex and iterative process, because there is no single unified approach that works for all types of problems. Finding the best ANN architecture typically involves selecting the number of layers and the number of nodes (neurons) in each layer, among other parameters.

How ANNs Work

Generally, the architecture of a supervised ANN is the fundamental process of how artificial neural networks operate. To elaborate further, let's break down the key components and processes involved in how neurons in different layers are interconnected and how they function (Goh 1995a, Specht 1991).

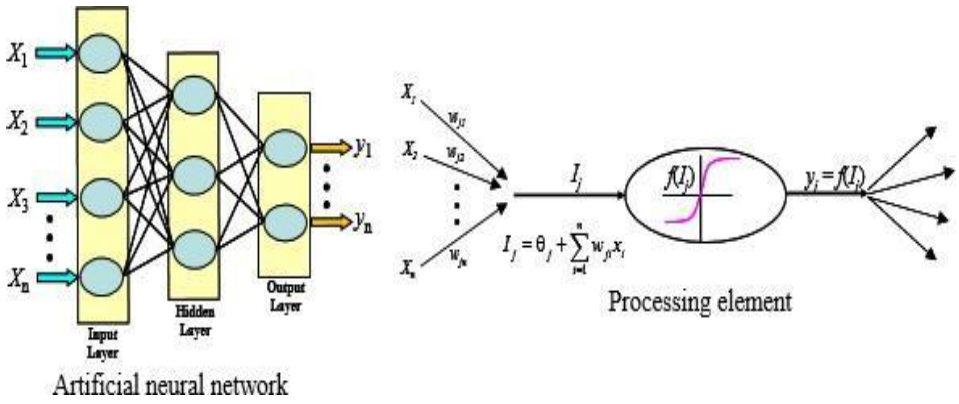

Figure 1: Representative structure and operation of ANNs (Goh 1995a, Specht 1991)

The connection is represented as follows.

(4)

$$I_j = \theta_j + \sum_{i=1}^{n} w_{ji} x_i$$

$$Yj = f(Ij)$$

Where, Ij = the activation level of node j; wji= the connection weight between nodes j and i; xi= the input from node i, i = 0, 1 …, n; θj = the bias or threshold for node j; yj = the output of node j; and f(.) = the transfer function wjixi.

2.4.Previous Studies

Prediction of undrained shear strength (Cu): Stroud (1974) proposed one of the most

popular relationships between SPT- N values and Cu. Several other researchers also tried to determine the correlation between q_u– SPT (N). Table 1 gives a summary of the correlations done before.

Table 1: Previous correlations of UCS

Researcher	Explanation	UCS(kPa)
Sanglerat, 1972	Clay and silty clay	12.5N, 10N
Terzaghi & Peck, 1967	Fine-grained soil	6.25N
Hara et al., 1974	Fine-grained soil	$_{29}0.72$
Sowers, 1979	Low, medium, and High plastic soil	12.5N, 7.5N, 3.75N
Nixon, 1982	Clay	12N
Stroud, 1974	PI<20, 20<PI<30, PI>30	(6-7)N, (4-5)N, 4.2N
Decourt, 1990	Clay	12.5N and 15N60
Ajayi & Balogun, 1988	Fine-grained soil	1.39N+74.2
Hettiarachchi & Brown, 2009	Fine-grained soil	4.1N60
Sirvikaya, 2009	UCS test	2.41N–0.82wn + 0.14LL + 1.44PI
Wroth & Wood, 1978	Clay	$_{170}-4.6$

NB: Where wn-natural moisture content, N-standard penetration test (number of blows), LL-liquid limit, PI-plasticity index, LI-liquidity index, Cu-undrained shear strength

3. Research Methods and Procedures

3.1.Location

The Addis Ababa Housing Development Program Office has conducted a soil investigation for the Bole Arabsa Condominium Building Site 6. On this building site, the office has dug 244 boreholes with a maximum depth of 10m and 15m below the natural ground surface for G+4 and G+7 buildings, respectively.

The study area is located in Addis Ababa, Bole Sub-city, around Bole Arabsa locality. These project sites are characterized by rising and falling topography with an average elevation of 2300m a.s.l.

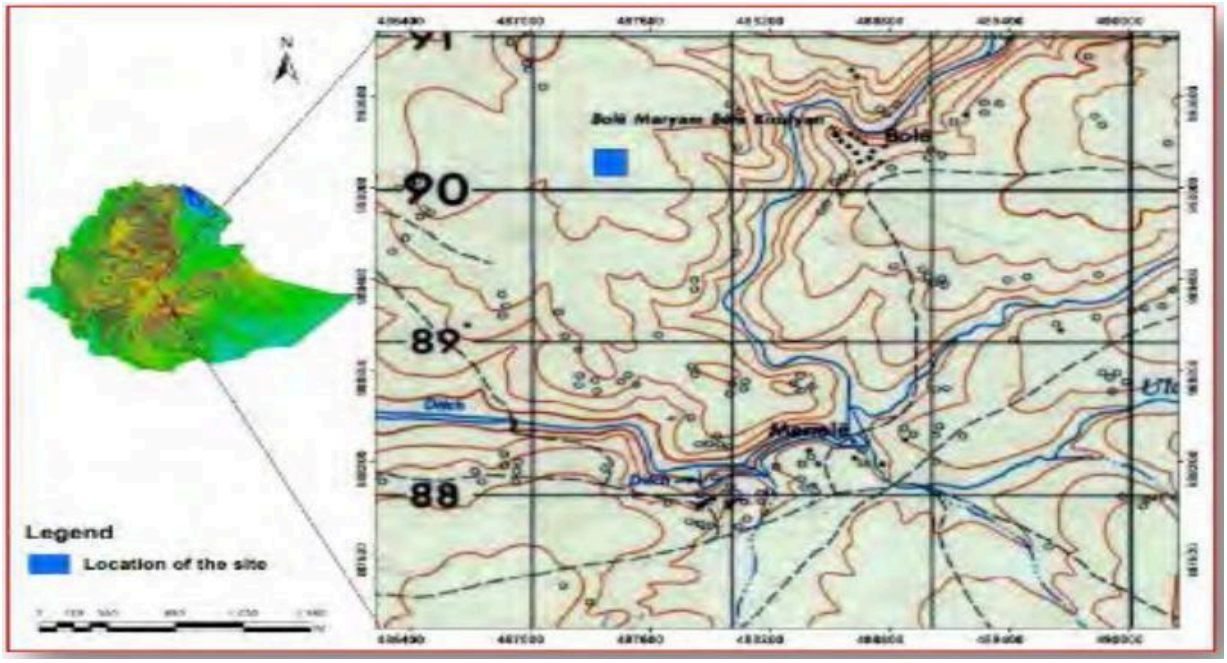

Figure 2: Location map of Bole Arabsa condominium site (Addis Ababa City Administration Integrated Land Information Center, 2015)

3.2.Data Filtering

To ensure the data is suitable for applying correlations in this independent project, 112 boreholes were selected from a total of 244 using the cluster random sampling method. The selected boreholes were chosen based on soil stratification and depth. The soil profiles in these boreholes generally consisted of silty clay and clayey silty sand in the upper, intermediate, and lower layers. For analysis, silty clay and clayey silty sand soil layers are selected with their respective thickness (1.50-3.10m, 3.10-5.10m, and 1.50-5.10m in depth).

The study utilized a total of 46 and 27 laboratory and field tests at depths of 1.50-3.10m and 3.10-5.10m, respectively. The effort was to relate undrained shear strength and index properties with the standard penetration test of silty clay soil. On the other hand, 61 laboratory and field test results are used at depth 1.50-5.10m to relate the index properties with the standard penetration test of clayey silty sand soil.

3.3.Research Design

In this particular study, the analysis was carried out by employing secondary data obtained from the Addis Ababa Housing and Construction Office. In this regard, the soil investigation report of the Bole Arabsa Condominium site was chosen for the research. The most prevalent

form of clay mineral in this region is montmorillonite, which gives the soil its expansive properties. The engineering property of expansive soil varies from place to place, and the research on the correlation of Cu with SPT and the Atterberg limit was established for the Bole Arabsa area. Furthermore, the prediction of Cu was made from simple test results such as liquid limit, plasticity index, and standard penetration test using ANNs based tool.

i) Modeling Approach

The data gathering process for a project involving secondary data from the Addis Ababa Housing Construction Office. It used MATLAB 2018, specifically its neural network toolbox, for numerical computation and visualization.

The training algorithm employed is the feed-forward back-propagation algorithm. This method involves passing inputs through the network, computing errors, and adjusting weights to minimize those errors iteratively. The coefficient of determination (R^2) and root mean square error (RMSE) are used to evaluate the performance of the developed ANN model.

Network architecture, which typically depends on the selection of input, output, and hidden layers as well as the number of neurons in each layer, is the most important factor in the computational complexity and performance of neural networks. The process of designing a neural network comprises determining the number of layers and neurons in each layer, as well as selecting an appropriate training algorithm. In general, the parameters of a neural network architecture are chosen through an iterative process of trial and error. This involves running the system multiple times to find the optimal number of neurons in the input and output layers, the number of hidden layers, and the number of neurons in each hidden layer.

To effectively train the neural network, it is crucial to carefully choose the size of the data set. An over-fitted model has an acceptable degree of accuracy while approximating the training data, but fails to have an effective generalization when applied to the validation data set. Conversely, an underfitted model would exhibit good generalization to the validation data set but would have a poor approximation of the training data. In order to mitigate the issues of over-fitting and under-fitting, the researcher needs to determine the optimal number of training observations.

In artificial neural network (ANN) models, the database is typically partitioned into three subsets: the training set, the validation set, and the testing set. The ANN utilizes a set of

examples from a training database as input, adjusts the weights with the respective learning algorithm, and generates an output using an activation function. Training is the process of modifying the network's connection weights by repeatedly exposing it to known input-output errors. Back-propagation learning, one of the many learning algorithms, is an effective training technique. One advantage of using the approach for optimization is the speed at which a trained artificial neural network (ANN) can generate outputs from inputs. In this approach, ANNs can be divided into layers, or subsets, that comprise neurons. The input layer contains information from the outside world that is fed into the ANN. Process elements in this layer transfer data to the hidden levels to react to input from the outside world. The hidden layer processes incoming data from the input layer before forwarding it to the output layer. By analyzing data from hidden layers, the output layer of the network generates output that corresponds to the data from the input layer.

ii) Methods of Data Analysis

The prediction of Cu using the ANN model required the following procedures to be followed:

1. Choosing the appropriate inputs for the model;
2. Data division and data pre-processing;
3. Selecting proper network architecture;
4. Meticulous selection of a few internal parameters that govern the optimization process, and
5. The stopping criteria and model validation.

4. Research Findings and Discussion

4.1. General

The structure and functional elements of biological neural networks serve as the basis for the ANN, a mathematical or computational model. A neural network is made up of an interconnected group of artificial neurons that process information using a connectionist computational technique. The number of neurons in the input layer, the number of hidden layers, the number of neurons in each hidden layer, and the number of neurons in the output layer are found using multiple repeated runs of the system, which is how the good performance value parameters of the NN architecture are determined by trial and error. ANN

analysis of undrained shear strength with standard penetration test, plastic index, and liquid limit of fine-grained soils was conducted in this study.

4.2.ANN Analysis of Undrained Shear Strength with Standard Penetration Test, Plastic Index, and Liquid Limit of Fine-grained Soils

i) Silty Clay Soil (at depth 3.10m to 5.10 m)

Model 1: Phase one deals with the correlation of the dependent variable (undrained shear strength) with each independent variable (SPT, LL, PI, WLL, and WPI). And the second phase analyses the correlation of undrained shear strength with a combination of independent variables SPT and LL, SPT and PI, LL and PI, SPT, LL and PI, SPT and WLL, SPT and WPI, WLL and WPI, and SPT, WLL and PI for silty clay (at depth 3.1m-5.10m).

The resulting NN analysis for the 27 available data for prediction, with its corresponding correlation coefficients, is computed in Table 2. The dependent variable in this study is undrained shear strength, while the independent variables are the Standard Penetration Test (SPT), liquid limit, and plasticity index. The dependent variable in this study is undrained shear strength, while the independent variables are the Standard Penetration Test (SPT), liquid limit, and plasticity index. The objective is to establish a relationship between the undrained shear strength and these independent variables. The performance of the model was assessed by comparing the measured (target) value with the output (predicted) values. The undrained shear strength has relativity strong correlation with SPT. The values predicted by the logsig-tansig type of ANN model show a strong alignment with the experimentally obtained Cu values. This model, which uses a logarithmic sigmoidal (logsig) activation function in combination with a tangent sigmoidal (tansig) transfer function, achieved R^2 values of 0.97872 for the training set, 0.97397 for the validation set, and 0.94525 for the testing set, demonstrating high accuracy across all stages of the analysis. Therefore, it is determined that the undrained.

Table 2: Performance indices Cu with SPT, LL, PI, WLL & WPI, silty clay (at depth 3.1m-5.1m)

Variable	N	Transfer unction	Training R	Test R	Validation R	All R
WLL vs Cu	19	tansig-purlin	0.99939	0.475	0.54196	0.9535
SPT VS CU	19	logsig-tansig	0.9787	0.94525	0.97397	0.95437
WPI vs Cu	17	logsig-tansig	0.89398	0.79504	0.41603	0.632
LL VS Cu	18	tansig-purlin	0.93584	0.3819	-0.57609	0.9015

PI vs Cu	18	logsig-tansig	0.88563	0.75306	0.51636	0.83393

The shear strength of silty clay soils included in this study could be predicted using trained ANNs. The SPT value have strong relation with undrained shear strength with better prediction performance.

Phase two: As already indicated above, the resulting NN analysis after associating undrained shear strength with a combination of standard penetration test, which is N adjusted, LL, PI, WLL, and WPI for 27 available data of silty clay soil. The prediction performance indices with corresponding correlation coefficients are stated in Table 3. Comparison of the measured value with the output (predicted) value from the relationship between the undrained shear strength and SPT, liquid limit, and plasticity index is done. From the analysis, undrained shear strength has a relatively strong correlation with a combination of standard penetration test, liquid limit, and plasticity index. It can be noted from the table that Cu values obtained from the ANN model are in good agreement with the experimentally obtained Cu values, as R^2 values of 1, 0.99, and 1 for training and validation.

Table 3: Performance indices Cu with SPT, LL, PI, WLL & WPI silty clay (3.1m-5.10m)

Variable	N	Function	Training R	Test R	Validation R	All R
SPT & WLL vs CU	22	tansig-purlin*	0.6377	-0.6547	0.9979	0.91391
SPT & WPI vs Cu	19	logsig-tansig	0.9855	0.3141	0.73672	0.94074
LLm& WPI vs Cu	22	logsig-tansig	0.9859	0.3863	0.53888	0.92891
SPT, WLL & WPI vs Cu	19	tansig-purlin	1	1	0.99	0.956
SPT & LL vs CU	19	tansig-tansig	0.9873	0.3666	-0.7494	0.94637
SPT & PI vs Cu	17	tansig-purlin	0.9871	0.997	0.75384	0.96568
LL & PI vs Cu	17	tansig-purlin	0.9971	0.3218	0.91136	0.97694
SPT, LL & PI vs Cu	19	logsig-tansig	0.994	0.4	0.3319	0.9549

* Purlin: pure linear and testing samples, respectively, with a transfer function tansig-purlin. Therefore, it is determined that the undrained silty clay soils included in this study could be predicted using a trained ANN combination of SPT, plasticity index, and liquid limit, which have a strong correlation with undrained shear strength and better prediction performance.

ii) Silty Clay Soil (at depth1.50m-3.10m)

Model 2: This model examines the **c**orrelation of undrained shear strength with SPT and LL. PI, WLL, and WPI, SPT and LL, SPT and PI, LL and PI and SPT, LL and PI, SPT and WLL, SPT and WPI, WLL and WPI and SPT, WLL and WPI for sandy silt (at depth 3.10m-5.1m).

This model has 2 phases.

Phase one: It shows the resulting NN analysis after correlating Cu with SPT, LL. PI, WLL, and WPI, for 46 available data sets of silty clay soil for the prediction of undrained shear strength. The performance indices of this, with corresponding correlation coefficients is shown in Table 4. The undrained shear strength has soundly correlated with the standard penetration test. It can be noted from the figure that Cu values obtained from the ANN model are in good agreement with the experimentally obtained (target) Cu values when using tansig-tansig transfer function, as R^2 of 0.93833, 0.9794, 0.90183 for training, validation, and testing samples, respectively. This model demonstrates that the undrained shear strength of silty clay soils can be accurately predicted using trained ANNs based on SPT values. The results show a strong relationship between SPT and undrained shear strength, leading to improved prediction accuracy.

Table 4: Performance indices Cu with SPT, LL, PI, WLL, and WPI sandy silt (1.50m-3.1m)

Variable	N	Transfer Function	Training R	Test R	Validation R	All R
WLL vs Cu	17	tansig-tansig	0.74097	0.39443	0.97163	0.61661
SPT vs Cu	17	tansig-tansig	0.93833	0.9794	0.90183	0.84462
WPI vs Cu	17	tansig-tansig	0.99672	-0.99273	0.53943	0.54382
LL vs Cu	13	tansig-tansig	0.71304	0.11877	0.88698	0.69918
PI vs Cu	17	logsig-tansig	0.58163	0.082426	0.72252	0.5428

Phase two: This phase exhibits the resulting NN analysis after correlating Cu with a combination of SPT and LL, SPT and PI, LL and PI, and SPT, LL, and PI of 46 available data of silty clay soil for the prediction of undrained shear strength. The performance indices of this, with corresponding correlation coefficients is noted in Table 5. Undrained shear strength values obtained from the ANN model have good agreement with the Cu of silty clay soils included in this study. They could be predicted using trained ANNs, SPT, LL & PI combined value to have a strong relation with Cu and better prediction performance.

Table 5: Performance indices Cu with SPT & LL, SPT & PI, LL & PI for silty clay (at depth 1.50m- 3.10m)

		Transfer	Training	Test	Validation	All

Variable	N	Function	R	R	R	R
WLL &WPIvs Cu	22	tansig-purlin	0.54321	0.82316	0.64329	0.5157
SPT &WLLvs CU	17	tansig-tansig	0.8789	0.15553	-0.2121	0.86891
SPT &WPIvs Cu	17	tansig-purlin	0.95247	-0.31833	-0.3055	0.791
SPT, WLL &WPIvs Cu	13	tansig-purlin	0.999	0.82121	0.99793	0.93846
SPT &LL vs Cu	21	logsig-tansig	0.92595	-0.17645	0.92803	0.86268
SPT & PI vs Cu	17	tansig-purlin	0.78454	0.34922	0.14217	0.70001
LL & PI vs Cu	17	tansig-purlin	0.80936	-0.65772	0.48656	0.58905
SPT, LL & PI vs Cu	22	tansig-purlin	0.89779	0.27988	0.95868	0.88684

iii) Clayey Silty Sands Soil

Model 3: Correlation of undrained shear strength (at depth 1.5m-5.1m). This is done in two phases.

Phase one: It deals with the resulting NN analysis after correlating Cu with SPT, LL. PI, LLm, and PIm, for 61 available data points of clayey silty sand. The prediction performance indices with corresponding correlation coefficients of undrained shear strength are presented in Table 6. This table shows experimental values with ANN results from the relationship between undrained shear strength with SPT, liquid limit, and plasticity index. The undrained shear strength has relativity strong correlation with the modified liquid limit. It can be noted that Cu values tansig-purlin transfer function, as R^2 of 0, 65707 0, 60274, 0.33208, for training, validation, and testing samples, respectively.

Table 6: Performance indices Cu with SPT, LL, PI, WLL, and WPI for clayey silty sand (1.5-5m)

Variable	N	Function	Training R	Test R	Validation R	All R
SPT VS CU	22	tansig-purlin	0.50709	0.43288	0.26165	0.46176
WPI vs Cu	23	tansig-tansig	0.58518	0.17354	0.67348	0.52237
WLL vs Cu	15	tansig-purlin	0.65707	0.33308	0.60274	0.58365
PI vs Cu	22	tansig-tansig	0.57537	0.03990	0.77258	0.52523
LL vs Cu	23	logsig-tansig	0.56959	0.03022	0.47719	0.50263

So, it is determined that the undrained shear strength of clayey silty sand soils included in this study could be predicted using trained ANNs modified liquid limit value, to show a relation with Cu.

Phase two shows the performance indices with corresponding correlation coefficients that resulted from NN analysis after correlating Cu with the combined prediction of Cu. This is

presented in Table 7.

Table 7: Performance indices Cu with combination SPT, LL. PI, WLL, and WPI, for clayey silty sand (at depth 1.5m-5.10m)

Variable	N	Transfer Function	Training R	Test R	Validation R	All R
SPT & WLL vs CU	23	tansig-tansig	0.91718	0.23558	0.94085	0.71389
SPT & WPI vs Cu	21	logsig-tansig	0.61775	-0.7521	0.56973	0.4974
WLL & WPI vs Cu	20	tansig-tansig	0.64835	0.1066	-0.4662	0.49522
SPT, WLL & WPI vs Cu	12	tansig-purlin	0.62198	-0.2964	0.55259	0.57653
SPT &LL vs CU	19	logsig-tansig	0.63074	0.71687	0.25568	0.60237
SPT & PI vs Cu	21	tansig-tansig	0.79659	0.27174	0.34394	0.62768
LL & PI vs Cu	22	tansig-purlin	0.72963	0.36938	0.30495	0.60195
SPT,LL & PI vs Cu	19	tansig-tansig	0.81105	0.13647	0.12949	0.61448

The Cu has relativity strong correlation with the combination of the standard penetration test and the modified liquid limit. Cu values obtained from the ANN model agree with the experimentally obtained (target) Cu values, tansig-tansig transfer function, with an R^2 of 0.91718, 0.94085, 0.23558, for training, validation, and testing samples, respectively. So, it is determined that the undrained clayey silty sand soils included in this study could be predicted using trained ANNs, the two independent variables SPT and modified liquid limit, with better accuracy.

5. Discussion

An ANN program was trained using the undrained shear strength results, and the program's output was compared to the experimental values. It is observed that the experimental results coincided with the ANNs' results. This shows that the ANN model is able to predict undrained shear strength quite efficiently.

Comparison ANN Model with Previously Developed Models

The performance indices calculated for the ANN models and the multiple regression analysis (MRA) model, developed by Addis Kebede (2012), with equation Cu = 5.931N-12.81 used in this study, are given in Table 8. On the basis of the performance indices in Table 3, both ANN models have demonstrated better prediction performance than MRA models. Hence, the calculated predictive models' efficiency is demonstrated by the values of the indices that were computed. In this study, the stronger relationship is a correlation of Cu with a combination of

SPT-N, liquid limit, and plasticity index, with R^2 of 1, 0.99, and 1 for training, validation, and testing samples, respectively, for silty clay soil.

Table 8: Performance indices (R2, MSE) of Cu, the ANN, and MRA models developed

Correlation	Model	data set use		R2	RMSE
Cu vs SPT-N	ANN1	Training	17	0.9787	2.874
		Validation	5	0.94525	
		Test	5	0.97397	
	ANN2	Training	38	0.93833	2.661
		Validation	4	0.9794	
		Test	4	0.90183	
Cu vs SPT-N	MRA	20		0.8819	

6. Conclusion and Recommendation

6.1.Conclusion

The ANN analysis showed that there is a relationship between the Atterberg limit and the undrained shear strength of fine-grained soil. Particularly liquid limit and plasticity index in combination with the SPT-N (N-70) value are powerful variables for the prediction of undrained shear strength. Particularly, for the silty clay soil, the model obtained using tansig-purlin transfer function shows a higher prediction performance, R^2 of 1, 0.99, 1 for training, validation, and testing samples, respectively. On the other hand, the model established for the clayey silty sand soil depicts that the tansig-tansig transfer function yields a better overall prediction performance, R^2 of 0.713.

Comparison was made between the performance indices of ANN and Regression analysis from the correlation of Cu & SPT-N values. Accordingly, the performance results obtained from the two models of ANN and RA were found to be 0.9659, 0.93985, and 0.8819, respectively. The artificial neural network model shows higher prediction performance than the multiple regression analysis model.

In conclusion, the artificial neural network model is superior to the multiple regression analysis model, which validates the usefulness of artificial neural networks in estimating undrained shear strength of the type of soil considered in this study.

6.2.Recommendations

6.2.1. Use of an artificial neural network-based model for the prediction of undrained shear strength has better prediction performance than empirical methods. However, in order to improve the results of the study, further research should be conducted in the field.

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APPENDICES

A-1 Artificial neural network silty clay soil (at depth3.10m-5.10m)

Model 2: Data for Correlation of undrained shear strength (Cu) with SPT, LL, WLL, PI, WPI, SPT and PI, SPT and PI, SPT, LL and PI, SPT and WLL, SPT and WPI, WLL and WPI, and SPT, WLL and WPI

Sr. No.	BH-ID	Depth	NMC	0.425 mm	Atterberg limit (AASHTO T89&90			USCS	Cu	SPT	N70	LLm	Pim
					LL	PL	PI						
1	BH-17	3.10-3.70	61.14	99.5	87	44	43	CH	26.58	7	9.96	86.56	42.78
2	BH-19	3.10-3.70	72.11	99.3	82	43	29	CH	38.64	4	4..72	81.42	28.79
3	BH-16	3.20-3.80	45.36	99.7	50	33	17	CH	29.22	5	6.78	49.85	16.95
4	BH-34	3.10-3.70	53.44	99.9	74	38	36	CH	30.9	6	7.92	73.92	35.96
5	BH-83	3.10-3.70	556.5	90.9	90	39	51	CH	40.24	9	10.41	81.81	46..36
6	BH-86	3.10-3.70	67.05	98.9	71	36	35	CH	33.73	6	7.58	70.22	34.61
7	BH-85	3.10-3.70	44.21	99.9	62	34	28	CH	18.68	8	13.58	61.94	27.97
8	BH-88	3.10-3.70	29.89	99.1	61	31	30	CH	30.98	11	14.5	60.45	29.73
9	BH-91	3.10-3.70	41.84	99.8	54	30	24	CH	39.76	7	8.14	53.89	23.95
10	BH-92	3.10-3.70	43.8	99.6	59	40	19	CH	31.5	8	10.46	58.70	18.90
11	BH-94	3.10-3.70	56.26	99.5	65	42	23	CH	40.5	6	6.92	64.67	22.8
12	BH-87	3.10-3.70	44.21	85.1	62	34	28	CH	33.62	8	10.12	52.76	23.83
13	BH-96	3.10-3.70	43.37	96.7	51	33	18	CH	46.78	7	7.51	49.31	17.40
14	BH-137	3.10-3.70	46.7	98.7	68	37	31	CH	40.44	7	8.12	79.94	33.53
15	BH-01	4.50-5.10	31.97	98	96	46	50	CH	33.63	15	18.98	94.08	49
16	BH-16	4.50-5.10	65.62	99.7	81	45	36	CH	19.14	9	15.09	80.75	35.89
17	BH-3	4.50-5.	63.41	99.2	75	44	30	CH	26.37	7	10	74.4	29.7

	4	10											6
18	BH-46	4.50-5.10	59.58	99.3	65	35	30	CH	35.04	7	8.68	64.54	29.76
19	BH-83	4.50-5.10	43.42	98.8	88	40	48	CH	34.62	11	1372	86.94	47.42
20	BH-86	4.50-5.10	45.4	99	64	31	33	CH	28.86	9	12.35	63.36	32.67
21	BH-91	4.50-5.10	46.68	95	52	31	21	CH	24.37	8	11.89	49.4	19.95
22	BH-95	4.50-5.10	38.07	97.9	46	27	19	CH	35.5	8	9.85	45.03	18.60
23	BH-84	4.50-5.10	46.82	99.2	79	28	51	CH	33.4	9	11.43	78.36	50.59
24	BH-80	4.50-5.10	57.62	98.8	68	42	26	CH	31.34	7	9.17	61.18	25..68
25	BH-85	4.50-5.10	34..61	98.7	64	31	33	CH	31.4	11	14.40	63.16	32.57
26	BH-88	4.50-5.10	36.93	97.9	93	43	50	CH	46	15	16.23	91.04	48.95
27	BH-92	4.50-5.10	41.15	99.7	78	34	44	CH	39.45	10	11.68	77.76	43.86

A-2 Artificial neural network analysis data of silty clay soil (at depth 1.5-3.10)

Model 1: Data for Correlation of untrained shear strength (Cu) with SPT, LL, WLL, PI, WPI, SPT and PI, SPT and PI, SPT, LL and PI, SPT and WLL, SPT and WPI, WLL and WPI, and SPT, WLL and WPI

Sr. No.	BH-ID	Depth	NMC	0.425 mn	Atterberg limit (AASHTO T89&90)			USCS	Cu	SPT	N70	LLm	Pim
					LL	PL	PI						
1	BH-01	1.50-2.10	56	99	70	27	43	CH	39.76	3	3.49	69.3	42.57
2	BH-02	1.50-2.10	37.98	99.4	98	79	19	CH	33.62	11	13.92	78.76	18.88
3	BH-03	1.50-2.10	25.99	99.8	81	61	20	CH	56.78	10	9.74	80.84	19.96
4	BH-06	1.50-2.10	45.33	99.7	79	56	23	CH	36.3	9	10.96	78.76	22.93
5	BH-07	1.50-2.10	43.72	99.3	72	50	22	CH	31.4	9	11.78	71.49	21.84
6	BH-16	1.50-2.10	55.14	99.6	95	47	48	CH	35.7	7	8.59	94.62	47.80
7	BH-27	1.50-2.10	56.07	98.6	95	50	45	CH	51.6	7	7.15	93.67	44.37
8	BH-18	1.50-2.10	60.92	99.3	72	47	25	CH	42.35	7	7.89	71.49	24.82

9	BH-26	1.50-2.10	66.75	99.6	87	49	38	CH	34.95	5	6.20	86.65	37.85
10	BH-30	1.50-2.10	29.22	97.2	68	49	19	CH	34.65	10	12.46	66.09	18.46
11	BH-32	1.50-2.10	46.75	95.4	71	46	25	CH	34.11	8	10.05	67.73	23.85
12	BH-34	1.50-2.10	42.85	99.8	73	49	24	CH	35.1	8	9.91	72.85	23.95
13	BH-45	1.50-2.10	26.32	85.1	64	53	11	CH	61.3	13	12.16	55.46	9.36
14	BH-50	1.50-2.10	31.52	99.5	49	27	22	CH	63.15	6	5.54	48.75	21.89
15	BH-58	1.50-2.10	55.01	97.3	65	40	25	CH	33.35	4	5.08	63.24	24.32
16	BH-68	1.50-2.10	51.73	98..3	51	22	29	CH	27.4	4	5.60	50.13	28.50
17	BH-69	1.50-2.10	31.9	98.7	91	76	15	CH	30.05	11	14.72	89.82	14.80
18	BH-83	1.50-2.10	49.53	88.8	64	35	29	CH	35.65	7	8.60	56.83	25.75
19	BH-85	1.50-2.10	53.3	99.7	74	52	22	CH	44.55	8	8.79	73.77	21.93
20	BH-86	1.50-2.10	49.86	99.4	63	36	27	CH	43.6	7	7.78	62.62	26.84
21	BH-90	1.50-2.10	42.23	99.7	65	38	27	CH	37.6	8	9.57	64.80	26.92
22	BH-92	1.50-2.10	46.25	99.2	64	40	24	CH	33.8	6	7.56	63.48	23.80
23	BH-95	1.50-2.10	50.13	99.2	63	26	37	CH	35.6	5	6.15	62.49	36.70
24	BH-94	1.50-2.10	51.18	99.4	72	34	38	CH	27.8	5	6.96	71.56	37.77
25	BH-84	1.50-2.10	52.26	99.6	86	58	28	CH	30	7	9.38	85.65	27.88
26	BH-70	1.50-2.10	46.65	86.1	61	42	19	CH	36.7	6	7.27	52.52	16.36
27	BH-01	2.50-3.00	42.83	99.7	83	51	32	CH	47.45	13	13.85	82.75	31.90
28	BH-02	2.50-3.00	47.79	99.9	86	46	40	CH	35.40	12	14.80	85.91	39.96
29	BH-03	2.50-3.00	46.15	98.9	94	48	46	CH	33.10	6	7.65	92.96	45.49
30	BH-05	2.50-3.00	31.53	99.9	82	40	42	CH	51.60	12	12.26	81.92	41.96
31	BH-25	2.50-3.00	41.83	99.8	82	38	44	CH	27.35	4	6.30	81.83	43.91
32	BH-26	2.50-3.00	53.01	98.7	91	46	45	CH	21.93	4	6.77	89.81	44.41
33	BH-34	2.50-3.10	50.17	99.5	74	38	36	CH	21.70	6	5.47	73.63	35.82
34	BH-45	2.50-3.00	59.10	98	85	38	47	CH	18.8	4	5.55	83.3	46.06
35	BH-46	2.50-3.00	37.38	96.9	80	37	43	CH	64.68	8	9.32	77.52	41.66
36	BH-83	2.50-3.10	52.20	99.4	80	39	41	CH	37.90	9	10.73	79.52	40.75

37	BH-87	2.50-3.00	36.36	99.3	72	34	38	CH	39.45	8	9.32	71.49	37.73
38	BH-99	2.50-3.00	42.46	99.4	79	35	44	CH	22.40	5	5.84	78.52	43.73
39	BH-101	2.50-3.00	23.00	99.3	45	31	14	CH	108.9	23	20.16	44.68	13.93
40	BH-195	2.50-3.00	25.55	96.9	50	26	24	CL	57.90	14	13.50	48.45	23.25
41	BH-196	2.50-3.00	25.14	99.9	68	29	39	CH	37.10	28	33.29	67.93	38.96
42	BH-212	2.50-3.00	17.23	99.5	42	28	14	CH	129.3	27	14.99	41.79	13.93
43	BH-223	2.50-3.00	19.30	99.4	38	26	12	CL	126.9	26	16.94	37.77	11.93
44	BH-230	2.50-3.10	25.02	98..7	74	40	34	CH	72.55	11	10.89	73.04	33.56
45	BH-231	2.50-3.10	24.74	98.8	46	27	19	CL	68.40	16	14.23	45.45	18.77
46	BH-235	2.50-3.00	44.88	97.9	72	37	35	CH	89.6	9	6.97	70.49	34.26

A-3 Artificial neural network clayey silty sand (at depth 1.5m-5.10m)

Model 3: Data for Correlation of undrained shear strength (Cu) with SPT, LL, WLL, PI, WPI, SPT and PI, SPT and PI, SPT, LL and PI, SPT and WLL, SPT and WPI, WLL and WPI, and SPT, WLL and WPI

Sr. N	BH-ID	Atterberg limit (AASHTO T89&90			0.42mm	USCS	Cu	SPT	N70	PIm	LLm
		LL	PL	PI							
1	BH-10	51	34	17	95.4	MH	39.76	7	8.14	48.65	16.22
2	BH-11	71	42	29	99.10	ML	40.5	5	5.76	70.36	28.74
3	BH-12	51	32	19	97.10	MH	33.62	9	11.43	49.52	18.45
4	BH-13	63	36	27	98.60	ML	36.3	6	7.59	62.12	26.62
5	BH-14	61	36	25	97.70	MH	35.7	7	8.59	59.59	24.42
6	BH-15	71	42	29	99.70	ML	51.6	8	8.17	70.78	28.91
7	BH-40	63	40	23	88	MH	42.35	6	6.76	55.44	20.2

											4
8	BH-42	67	36	31	99.10	MH	34.95	4	4.96	66.39	30.72
9	BH-61	64	41	23	90.5	MH	34.65	13	16.20	57.92	20.81
10	BH-62	45	34	11	92.1	ML	34.11	8	10.05	41.44	10.13
11	BH-63	55	37	18	85.4	MH	60.6	11	10.38	46.97	15.37
12	BH-76	65	40	27	88.6	MH	35.1	9	11.15	57.59	23.92
13	BH-77	67	42	25	97.8	MH	61.3	5	6.25	65.52	24.45
14	BH-131	51	35	16	88.3	MH	63.15	7	8.31	45.03	14.13
15	BH-135	37	27	15	80.2	ML	33.35	8	8.92	29.67	12.03
16	BH-220	53	36	17	73.7	MH	27.4	14	19.63	39.06	12..53
17	BH-12	69	43	26	99.7	MH	30.05	5	6.69	68.79	25.92
18	BH-13	49	30	19	97.1	ML	35.65	7	8.60	47.58	18.45
19	BH-14	49	28	21	98.6	MH	44.55	7	7.69	47.58	20.39
20	BH-40	68	58	10	99.6	MH	43.6	8	8.89	67.73	9.96
21	BH-42	61	39	22	97.8	MH	37.6	7	8.37	59.66	21.51
22	BH-61	54	43	11	82..7	MH	33.8	17	21.46	44.66	9.09
23	BH-67	39	29	10	68	MH	35.6	14	17.22	26..52	6.8
24	BH-22	51	28	23	98.5	MH	27.8	4	5.56	50.23	22.65
25	BH-24	46	31	15	71.6	ML	30	26	34.84	32.93	10.74
26	BH-02	52	33	19	98.1	MH	33.6	9	11.39	51.01	18.64
27	BH-04	34	27	7	98.3	ML	40.9	7	10.33	33.42	6.88
28	BH-08	55	32	23	99.2	MH	39.15	5	5.86	54.56	22..81
29	BH-09	46	22	24	98.9	ML	28.4	4	5.50	45.49	23.73
30	BH-12	63	53	10	61.2	MH	36.75	7	8.47	38.55	6.12
31	BH-13	58	47	11	65.3	MH	34.55	15	18.7	37.87	7.18

									3		
32	BH-14	52	36	16	99.3	MH	35.23	5	6.18	51.63	15.88
33	BH-15	45	31	14	51.1	SM	36.45	15	18.23	22.99	7.15
34	BH-39	57	32	25	87.1	MH	53.3	9	9.04	49.64	21.77
35	BH-41	47	30	17	99.3	ML	55.95	5	4.90	46.67	16.88
36	BH-78	50	35	15	76.2	ML	48.01	13	13.77	38.1	11.43
37	BH-219	79	51	28	59.5	MH	45.55	6	7.19	47	16.66
38	BH-220	54	39	24	79.4	MH	60.4	13	12.27	42.87	19.05
39	BH-132	53	42	11	76.1	MH	37.5	8	9.58	40.33	8.37
40	BH-96	39	25	14	96.6	ML	36.15	11	13.42	37..67	13.52
41	BH-136	54	31	23	97.3	MH	48.18	9	9.45	52.54	22.38
42	BH-138	71	56	15	98.9	MH	38.55	13	15.36	70.22	14.83
43	BH-41	49	28	21	99.3	MH	42.55	6	6.75	48.65	20.85
44	BH-43	49	29	19	99.3	MH	38.62	4	4.72	48.65	18.86
45	BH-44	49	31	18	96.6	ML	33.1	5	6.38	47.33	17.38
46	BH-27	60	39	21	98.6	MH	22.7	4	6.15	59.16	20.70
47	BH-28	54	40	14	96.6	MH	24.9	11	16.18	52.16	13.52
48	BH-29	53	28	25	98.6	MH	38.8	4	4.71	52.26	24.65
49	BH-30	62	42	20	96.1	MH	34.4	6	7.50	59..58	19.22
50	BH-31	63	39	24	98.9	MH	37.3	4	4.80	62.30	23.73
51	BH-32	67	50	17	99.4	MH	43.05	10	11.19	66.59	16.89
52	BH-33	64	46	18	78.3	MH	42.1	10	11.31	50.11	14.09
53	BH-35	52	32	20	90.7	MH	38.9	8	9.41	47.16	18.14
54	BH-36	51	35	16	98.9	MH	37.4	5	6	50.44	15.8

											2
55	BH-57	52	37	15	99.6	MH	37.9	12	14.3	51.79	14.94
56	BH-77	40	29	11	79	ML	36.55	20	24.27	31.6	8.69
57	BH-78	58	39	19	77.9	MH	30.1	5	6.68	45.18	14.80
58	BH-80	51	32	19	94.7	MH	42	7	7.92	48.29	17.99
59	BH-81	57	36	21	91.3	MH	38.2	7	8.3	52.04	19.17
60	BH-42	51	31	20	98.6	MH	42.55	5	5.62	50.28	19.92
61	BH-43	69	42	27	99.3	MH	37.5	4	4.79	68.51	26.81

Contributions of Antisocial Personality Disordered Substance Abuse to Recidivism in West Arsi Zone Correctional Administration Office

Zerihun Ayana

Abstract

The purpose of this study was to examine the contribution of substance abuse and antisocial personality disorder (ASPD) to recidivism among offenders of the West Arsi Zone Correctional Administration Office. To understand the link between recidivism and substance abuse problems, as well as recidivism and antisocial personality disorder, a correlational research design was utilized. To collect data for the study, the Mini International Neuropsychiatric Interview (M.I.N.I) questionnaire and the CAGE (Cut down, Annoyed, Guilty, and Eye-opener) questionnaires were used. The sample of 310 (286 males and 24 females) was selected by using a systematic random sampling technique from the 1602 target population. The data were analysed using percentages, cross-tabulation, chi-square test, and binary logistic regression. The results revealed that the prevalence of recidivism is 21.6%, ASPD is 38.4%, and substance abuse is 34.7% (Alcohol Abuse is 40%, khat, tobacco, and hashish abuse accounts 37.4%, 33.2% & 28.1%, respectively). Moreover, from hashish abusers, 66.7%, from offenders who met ASPD, 50.4%, from alcohol abusers, 48.4%, from khat abusers, 44.8%, and from tobacco abusers, 42.7% were recidivists. A Pearson chi-square test result shows that there is a significant relationship between the age of respondents and recidivism (X^2= 10.917, df = 3, n 310, p=.012), recidivism and marital status (X^2=17.802, df = 2, n=310, p=.000), and recidivism and place of residence (X^2= 9.811, df= 1, n=310, p=.002). Additionally, Phi and Cramer's V value showed that the age of respondents, marital status, and educational level had a positive and weak relation with recidivism. Furthermore, ASPD and hashish abuse significantly contribute to recidivism. Accordingly, offenders who had ASPD were more recidivists than offenders who did not meet ASPD criteria. Similarly, offenders who abuse hashish were more recidivist than offenders who did not abuse the same. The researcher suggests prevention and treatment of substance abuse, as well as the intervention of ASPD, by focusing on developing skills of how to meet their needs in a pro-social rather than antisocial way.

Keywords: Antisocial personality disorder, substance abuse, recidivism.

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1. Introduction

1.1.Background

Blumstein and Larson (1971) defined recidivism as a falling back into prior criminal habits, especially after punishment or release from prison. Similarly, recidivism in the context of the criminal justice system refers to a return to imprisonment in any penal institution after being released from prison. It can incorporate permanent re-imprisonment, parole revocation, new convictions, and court-ordered returns to facilities (Bailey, 2007). Likewise, recidivism is sometimes defined as the re-arrest, reconviction, or re-imprisonment of an ex-prisoner within a given time frame. (Aborn and Boegem, 2011).

Globally, there is no consensus among social science scholars, especially criminologists, on the significant determinants of recidivism among prisoners. However, different factors were associated with the risk of recidivism depending on its type. Factors influencing the prevalence rate of recidivism and criminal activities by relapsed criminals are complex phenomena like the interaction of psychological, sociocultural, biological, and other factors (Visher *et al.* 1991).

According to the report of the Criminal Justice Initiative (CJI) of the Open Society Foundation for South Africa (OSF-SA) Recidivism and Reoffending Conference of 2010 states that the recidivism rate in South Africa is between 80% and 90%. In 2002, the United States Department of Justice's Bureau of Statistics published one of the largest and best-known studies, which found that among nearly 300,000 prisoners released in 15 states in 1994, 67.5% were rearrested within 3 years, 46.9% were convicted for a new crime, and 51.8% were re-imprisoned (Steyn, 2010).

Among several factors that contribute to recidivism, substance abuse is the major and highly prevalent one among the prison population. Accordingly, it is a widespread problem among the prison population, with re‑addiction after release a frequent cause of recidivism and a barrier to obtaining stable employment (Lise and Charles, 2004). Drug-using individuals are more likely to re-offend, with differential probabilities depending on drug type and frequency of use (Makkai *et al.* 2004; Putnins, 2003; Salmenainen, 1995; Stevenson and Forsythe, 1998).

On the other hand, antisocial personality disorder (ASPD), also called psychopathy, is a prominent disorder used to explain criminal behavior. ASPD was listed in the American Psychiatric Association's Diagnostic and Statistical Manual-IV TR (DSM-IV). ASPD has been closely studied in connection with crime and delinquency (Shoemaker, 2009; Siegel *et al*., 2010).

The criteria for the disorder include a pattern of violation of the rights of others, including law-breaking activities that began in childhood or early adolescence (DSM-IV, 2000).

According to the DSM-5, the highest prevalence rate of antisocial personality disorder is greater than 70% among the most severe samples of males with alcohol use disorder and from substance abuse clinics, prisons, or other forensic settings. Prevalence is higher in samples affected by adverse socioeconomic (i.e., poverty) or socio-cultural (i.e., migration) factors.

In different countries of the world, there are different prevalence rates of recidivism as well as different factors that contribute to recidivism. Psychological problems like substance abuse and antisocial personality disorder contribute greatly to recidivism problems. As the study conducted by Arroyo and Ortega (2009) shows, 30% of the prison population has a personality disorder. From the stated figure, both Antisocial and Borderline Personality Disorder account for 24%. Men had a higher prevalence of alcohol abuse and antisocial personality (Watzke *et al*. 2006).

According to the researcher's observation, in most parts of our country, the use of substances such as alcohol, *khat*, tobacco, and hashish is widespread, particularly among young people. Furthermore, certain substances are permitted for use in Ethiopia's correctional facilities. For example, smoking tobacco is permitted in almost all correctional institutions, whereas chewing *khat* is common in Harar correctional institutions, and most offenders have developed a dependency on those substances. As a result, using these substances may contribute to recidivism in some form or another.

In Ethiopia, there are no studies conducted to assess the contribution of ASPD and substance abuse to recidivism. Accordingly, the issue of recidivism becomes a constant headache for the correctional staff of the country. Therefore, this study is important since it contributed largely to the existing knowledge, to the correction and rehabilitation work, and it can serve as a good base for other scientific researchers interested in conducting studies in the area.

As far as the researcher is aware, no studies have been conducted or published in Ethiopia to evaluate the role of ASPD and substance abuse in recidivism. On the other hand, recidivism has become a constant source of frustration for correctional officers. As a result, this study is significant because it has greatly contributed to existing knowledge, correction, and rehabilitation work, and it can serve as a solid foundation for other scientific researchers interested in conducting research in the same or related fields.

1.2.Statement of the Problem

It is well known that the diagnoses of either personality disorder or substance use disorder are associated with an increased risk of recidivism in criminals (Asnis *et al.* 1997). Similarly, according to White and Gorman (2002), drug and alcohol use are considered important factors in criminal offending.

As it is possible to understand from studies conducted in different countries, antisocial personality disorder and substance abuse problems are the two main factors highly related to recidivism. To solve the recidivism problem, most correctional administration offices prevent recidivists from being released on parole. Additionally, according to the regional rules and regulations of the correctional administration, the parole system is allowed only for non-recidivists and prisoners who respect the rules and regulations of the administration's offices.

As indicated by different researchers such as Hasglul (2014) and Aggarwal (2013), the prevalence of mental health problems like substance abuse and antisocial personality disorder is high in the prison population.

As far as this researcher is aware, no study has been conducted to estimate the prevalence of psychological problems such as substance abuse, antisocial personality disorder, and other similar issues that might negatively affect offenders' correction and rehabilitation work, as well as national development. To provide effective and efficient correctional and rehabilitation services, it is critical to estimate the prevalence of these issues as well as the relationship between them and recidivism.

So, the main reason why this research was conducted was to examine the contribution of antisocial personality disorder and substance abuse (alcohol, khat, tobacco, and hashish abuse) to recidivism, to estimate the prevalence of recidivism, substance abuse, and antisocial personality disorder, and to identify which socio-demographic characteristics of respondents is associated with recidivism among offenders in the West Arsi Zone Correctional Administration.

Accordingly, the following research questions were answered at the end of the study: -

1. What is the prevalence of recidivism, antisocial personality disorder, and substance abuse problems among offenders of the West Arsi Zone Correctional Administration Office?

2. Do antisocial personality disorder and substance abuse (alcohol, *khat,* tobacco, and Hashish abuse) contribute to recidivism?

1.3.Objectives of the Study

i) General Objective

The general objective of this study was to examine the contributions of antisocial personality disorder and substance abuse to recidivism among offenders in the West Arsi Zone Correctional Administration Office.

ii) Specific Objectives

This study had the following specific objectives: -

- To estimate the prevalence of recidivism, substance abuse, and antisocial personality disorder among offenders in the West Arsi Zone Correctional Administration Office, and
- To examine the contribution of antisocial personality disorder and substance abuse (alcohol, khat, tobacco, and hashish abuse) to recidivism.

1.4.Significance of the Study

Primarily, it is hoped that this study would enable the Oromia Correctional Administration Commission, especially the West Arsi Zone Correctional Administration Office, to have a good understanding of the contributions of substance abuse and antisocial personality disorder to recidivism that contribute to the rehabilitation efforts of offenders effectively and to reduce the number of recidivists. Similarly, the study would enable different stakeholders working with correctional administrations to have a good understanding of recidivism issues and those psychological problems that contribute to working in collaboration for correcting and rehabilitating offenders, as well as re-offenders. Secondly, the study remains important for those offenders who have antisocial personality disorder and substance abuse problems for further psychological assessment and treatment. Thirdly, it is important for other researchers who are interested in conducting research in the area.

1.5.Delimitation of the Study

This study was delimited only to estimate the prevalence of recidivism, substance abuse problems, and antisocial personality disorder of offenders who were imprisoned in the West Arsi

Zone Correctional Administration Office during the data collection period (March 01, 2015, to March 20, 2015). This is also to examine the association between recidivism and socio-demographic characteristics of the respondents, to assess the contributions of antisocial personality disorder and substance abuse (alcohol, *khat*, tobacco, and hashish abuse) to recidivism.

1.6.Operational Definition of Terms

In this study, the following terms are defined as follows:

- ***Recidivism*** is a condition by which an ex-prisoner is re-imprisoned in correctional institutions twice or more times within five years after being released from prison for committing a crime.
- ***Substance abuse*** **is** an addiction or a problem of using alcohol, tobacco, *khat,* or hashish that may develop a dependence on drugs, causing a compulsion to continue using the substance because it gives them a feeling of well-being.
- ***Antisocial personality disorder*** is a type of personality disorder characterized by a pervasive pattern of disregard for and violation of the rights of others that begins in childhood or early adolescence and continues into adulthood**.**

2. Review of Related Literature

2.1.Overview of Crime and Criminal Behavior

Crimes are acts or omissions that violate the law and can result in imprisonment and/or a fine. Rape, murder, child neglect, robbery, burglary, drunken driving, and failure to pay taxes are all common types of crimes. However, as several well-known criminologists, such as Sampson and Laub (1993), Gottfredson and Hirschi (1990), have recently stated, the key to understanding crime is to focus on the fundamental characteristics of all criminal behaviors rather than specific criminal acts.

Whereas the behavioral definition of crime emphasizes criminality as a certain personality profile that causes the most alarming sorts of crimes. All criminal behaviors involve the use of force, fraud, or stealth to obtain material or symbolic resources. According to Gottfredson and Hirschi (1990), criminality is a style of strategic behavior characterized by low self-control, indifference to the suffering and needs of others, and self-centeredness.

Criminal behavior is the product of a systematic process that involves complex interactions between individual, societal, and ecological factors over the course of our lives. In other words, from conception onward, the intellectual, emotional, and physical attributes we develop are strongly influenced by our personal behaviors and physical processes, interactions with the physical environment, and interactions with other people, groups, and institutions. These systematic processes affect the transmission from generation to generation of traits associated with increased involvement in crime.

Psychologists and psychiatrists study criminal behavior for what it reveals about individual human propensities, whereas sociologists study crime for what it says about society. The study of individual criminals is the focus of psychologists, who relate criminal behavior to the personal attributes, histories, or immediate situations of offenders. Criminology is the study of illegal acts, the laws that define illegal acts as criminal, and how society seeks to control and prevent those criminal acts. Rehabilitation assumes that crime results from personal deficiencies or maladjustment. Attention is, therefore, focused on the individual criminal rather than the crime (Williams, 1978).

i) Recidivism and its Prevalence

According to Blumstein and Larson (1971), recidivism is a condition in which an ex-offender again goes back to prior criminal habits after being released from a prison institution. Similarly, recidivism in the criminal justice system refers to the re-imprisonment of an ex-prisoner by committing a crime after being released from such a facility. It can incorporate permanent reincarceration, parole revocation, new convictions, and court-ordered returns to facilities (Bailey, 2007).

According to Nathan (2014), there are two competing ideas about what recidivism should mean. One group argues that new contact with the criminal justice system, including those who commit minor crimes, can be considered as recidivism. Whereas, the other group argues recidivism should mean the commission of a new crime by an ex-prisoner resulting in a new sentence.

In Ethiopia, recidivism is defined as an individual committing a similar or new crime for the second or more time within five years and remaining incarcerated after being released from a prison institution on parole or pardon with the expectation that he or she has been corrected. To reduce recidivism, public prosecutors request that courts punish them severely; similarly, the

court considers whether the individual is a recidivist or not; if the individual is a recidivist, punishment will be severe, and prison institutions prohibit recidivists from being paroled.

According to the statistics released by the US Department of Justice in 2001, 44% of ex-offenders were rearrested in the same year after being released from a prison institution. Prisoners who had the highest re-arrest rates were car thieves, burglars, and robbers, with a rate of 78%, 74% & 70% respectively (Bureau of Justice Statistics, 2002).

In addition to this, by the end of the five-year follow-up period, about 76.6% of prisoners released in 2005 were rearrested in the US; most of whom (43.4%) were rearrested within one year of being released. As it is possible to understand from the five-year follow-up period data, property offenders were rearrested (82.1%) more than other types of crimes, like drug offenders (76.9%), public order offenders (73.6%), and violent offenders (71.3%) (Nathan**,** 2014).

Moreover, the Bureau of Justice Statistics also found that prisoners with longer criminal histories were more likely to be rearrested within five years of being released. Data show that 86.5% of released prisoners with 10 or more prior arrests were rearrested within five years. In comparison, 60.8% of released prisoners with four or fewer prior arrests and 75.9% of released prisoners with five to nine prior arrests were rearrested within five years.

Similarly, according to the research done by Abrifor (2011), in Nigeria, there were persistent rise in the prevalence of recidivism from 35% in 2007 to 44% in 2008 and 52.4% in 2010. The trend and pattern of recidivism indicate that male recidivists account for 88.5% whereas, whereas females are 11.5%. The prevalence was high among young offenders of 26-35 years of age, which accounts for 54%, 36 -45 years (22.2%), and 16 -25 years (21.2%). In this study, theft and other minor stealing account for 20.3%, armed robbery 11.3%, and burglary 9.0%. Female recidivists were imprisoned for anger-related offenses such as murder (10.1%) and attempted murder cases (6.2%). Regarding the number of times of recidivism, it is revealed that the majority of the respondents have been convicted twice, accounting for 42.7 % (242), while 29.5% (167) were convicted three times, and 24.5 % (139) were convicted four times. However, 2.6% (15) and 1.1% (7) accounted for those convicted five times and six times and above.

In another way, the studies conducted in Kampala district alone indicate that recidivism among offenders on community service was at a rate of 9% whereas, whereas the national recidivism rate was 6%. However, the data obtained from the community service secretariat indicates that

the rate of recidivism in Kampala has risen to 12% (Ssebuggwawo, 2010). Similarly, according to the report of the Criminal Justice Initiative (CJI) of Open Society Foundation for South Africa (OSF-SA), the recidivism and reoffending conference of 2010 states that the recidivism rate in South Africa is between 80% and 90%.

ii) Antisocial Personality Disorder

The American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) describes antisocial personality disorder (ASPD) as "*a pervasive pattern of disregard for, and violation of the rights of others that begins in childhood or early adolescence and continues into adulthood"* (American Psychiatric Association, 1994). In another way, the World Health Organization's International Classification of Diseases (ICD-10) calls it Dissocial Personality Disorder and describes it as a "*personality disorder characterized by disregard for social obligations and callous unconcern for the feelings of others*". There is continuous debate in the literature about whether ASPD shares a common referent with psychopathy and sociopath, but in any event, their operational measures are rather different.

An antisocial personality disorder is characterized by a pervasive pattern of socially irresponsible, exploitative, and guiltless behavior. ASPD has a prevalence of between 3.9% and 5.8% in men and 0.5% and 1.9% in women in the US general population. The disorder is associated with substance misuse, significant psychosocial impairment, domestic violence, and depression; suicide is an all-too-common outcome. Family and marital relationships are frequently disrupted in persons with ASPD, and healthcare utilization is excessive. The prevalence of ASPD is higher in correctional than in psychiatric settings. In prison, offenders with ASPD can present considerable management problems because of their disregard for the rights of others, aggression, lack of remorse, and irritability (Loots and Louw, 2011).

iii) Prevalence of Antisocial Personality Disorder Among the Prison Population

Black and Larsen (2000) reported that almost 80% of men and 65% of women in U.S. prisons meet the criteria for *ASPD*, meaning that the disorder is prevalent among those who are actively criminal. Similarly, according to the study conducted by Langeveld and Melhus (2004), the prevalence rate of personality disorders was 80%, and antisocial personality disorder accounted for 60%. In a systematic review of 62 surveys, it was reported that 65% of the men had

personality disorders, with 47% having antisocial personality disorder. 42% of the women had a personality disorder, and 21% had an antisocial personality disorder (Fazel and Danesh, 2002).

Arroyo and Ortega (2009) mentioned in their study that 30% of imprisoned offenders were observed to have personality disorders. The distribution of personality disorders was 12% with Antisocial Disorder, 12% with Borderline Disorder, 3% with Paranoid Disorder, 2% with Narcissistic Disorder, and 2% and Schizoid Disorder. Studies have reported that 50% of mentally ill patients also have a personality disorder. The prevalence of alcohol abuse and antisocial personality was high in men, whereas anxiety disorders, depression, and borderline personality disorders were more prevalent among women (Watzke *et al.* 2006).

Similarly, Sonja and Dap (2011) did a study by taking a sample of 500 South African male offenders to measure the prevalence rate of antisocial personality disorder. As the study indicates, 42% of the total sample meets the criteria for dissocial personality disorder, 27% represented psychopathy, whereas the prevalence of antisocial personality disorder in this sample represented 17%. In prison populations, rates of psychopathy are much higher at about 20%, and it is estimated that psychopaths commit 50% of serious crimes (Hare, 1991).

iv) Substance Abuse and Crime

In the United States from 1980-2003, the number of inmates increased from 501,886 to 2,212,475; whereas, the number of state prison was increased by more than 300% to 1, 226,175 (Harrison and Beck, 2004). These numbers were increased mainly because of drug-related crimes (Belenko, 2000; Belenko and Peugh, 1999).

Similarly, as Miller and his research colleagues (2006) estimated, in the USA, only in 1999, 5.4 million violent crimes and 8 million property crimes involved alcohol and other drug use. Drug users report greater involvement with crime than non-users and are more likely to have criminal records. Individuals with criminal records are much more likely to be drug users than others. Individuals who use drugs report that they are involved in crime more than those who do not use them. In another way, individuals who have criminal records are much more likely to be drug users than others.

According to a study analyzed by Fazel, Bainsand Doll (2006), by reviewing thirteen studies with 7,563 prisoners who met the review criteria estimates the prevalence of alcohol abuse and dependence in male prisoners ranged from 18% to 30%, and 10% to 24% in female prisoners.

The prevalence of drug abuse and dependence varied from 10% to 48% in male prisoners and 30% to 60% in female prisoners. The United Nations General Assembly (UNGA) session, through its resolution 65/231 on the United Nations African Institute for the Prevention of Crime and Treatment of Offenders (UNAFRI), affirmed that "*the devastating impact of new and more dynamic crime trends on national economies of African states poses a major obstacle to harmonious and sustainable development in Africa*. According to the UNAFRI report, drugs, in particular alcohol and marijuana, were reported to be major causes of road accidents, thefts, assaults, rape, defilement, terrorism, and murder.

There are very few studies on substance use among prisoners in Africa as compared to the western countries. One of the studies on this subject in Africa indicates that the lifetime drug use among prisoners in Uganda was 65% and that the most commonly abused drugs were tobacco/cigarettes (90%), marijuana (49%), khat/mairungi /Catha edulis (17%), and alcohol (2%). Unlike the studies from developed countries, there was no reported injecting drug use in Uganda (Kinyanjui and Atwoli, 2013).

According to the study conducted in western Kenya in Eldoret prison, the prevalence of substance use was 66.1%, while that of alcohol use was 65.1%. Both substance and alcohol use were significantly associated with male gender, urban residence, and those who have higher levels of education. The prevalence of cigarette use was 32.7%, while 22.5% admitted to chewing tobacco. Factors significantly associated with tobacco use were male gender, urban residents, being single, younger age, and lack of income in the past year. The prevalence of cannabis use was 21%, and this was associated with male gender, urban residence, being single, and being a student in the prior year.

2.2.Types of Substances Used in Prisons

i) Alcohol

According to the WHO (2010) report, all over the world, alcohol and illegal drug use account for 5.4% of the world's annual disease burden; similarly, tobacco is responsible for 3.7% (WHO, 2010). While research has shown that it is difficult to demonstrate a clear causal relationship between alcohol and violent crime, the British Medical Association has estimated that either the offender or victim has consumed alcohol in 65% of homicides, 75% of stabbings, and 70% of

assaults. In the UK, it has been estimated that 78% of assaults are committed under the influence of alcohol (Prime Minister's Strategy, 2003).

Williams *et al.* (2008), in their study in a Nigerian prison, found that in terms of lifetime use of any substance, alcohol use was reportedly the highest, which accounts for 77.5% among prisoners. In France, in 2003, more than 30% of the prisoners reported alcohol abuse, and they regularly used drugs for about 12 months of their prior imprisonment (Mouquet *et al.* 2005). In the Lithuanian prison study (Narkauskaitė *et al.* 2007), 92.1% of prisoners reported that they used alcohol at least once in their lives. A New Zealand study indicates that 81% of the prisoners had a lifetime alcohol disorder, and 39% of them had symptoms in the 6 months before imprisonment. Half of the prisoners had met the criteria for an alcohol-dependence syndrome. Alcohol disorder is more prevalent in the prison population than in the general population; it is twice as prevalent in the former case as in the latter one (Bushnell *et al.* 1997).

Almost all juveniles had used at least one substance before their current period of imprisonment. By drug type, a greater number of juveniles had used alcohol (97%) than cannabis (94%), amphetamines (50%), inhalants (37%), or ecstasy (33%). In another way, 70% of youths reported that they were under the influence of substances at the time of committing the crime, leading to their imprisonment. This rate is higher than reported by imprisoned adult males (62%) and adult females (58%) about the offenses for which they had been imprisoned. Similar numbers of juveniles reported that at the time of the offense, they were intoxicated by drugs (24%), alcohol (22%), or both (24%) (Makkai and Payne, 2003).

According to the study conducted in western Kenya in Eldoret prison, the prevalence of substance use was 66.1%, while that of alcohol use was 65.1%. Both substance and alcohol use were significantly associated with male gender, urban residence, and those who have higher levels of education (Kinyanjui and Atwoli, 2013).

ii) Khat

The number of *khat* chewers has significantly increased in Ethiopia, and its consumption has become popular in all segments of the Ethiopian population. Previously, *khat* was mainly cultivated in the eastern part of Ethiopia. Nowadays, it has grown in all parts of the country.

As it is possible to understand from a survey conducted in 1997 by taking a sample of 1200 adults in rural communities, the prevalence of use of *khat* was 32%, among the staff of Jimma

University, and the Jimma City community was found to be 30.75 % and 30.6 %, respectively. Similarly, the prevalence of it in Adami Tulu was 31.7%, among students of Gondar College of Medical Sciences, 22.3%, in Butajira town, 50%, and also a prevalence of *khat* use of 44% was found in an Ethiopian sample of 25 juvenile delinquents drawn from the National Remand Home in Addis Ababa. Similarly, a study conducted by Alem *et al.* (1999) on a large survey of 10,468 adults in rural Ethiopia reports that 55.7% of the sample had used *khat* at some time in their lives and that 50% were current users.

Chewing of *khat* was also significantly related to physical illness, injuries, undernutrition, and mental distress. Similarly, sleep disturbance was also higher among *kha*t users than non-users (Tekalign *et al.* 2011).

Among prisoners in Uganda, the prevalence of *khat* use was 17%. (Kinyanjui and Atwoli, 2013). Moreover, the United Nations Office on Drugs and Crime (UNODC) reported that approximately 72% of Yemeni men and 32.6% of women used *khat* in 2006, and another study done in the urban setting of Yemen found that 800 adults in an urban setting had lifetime use rates of 81.6% in men and 43.3% in women. Current adult users of *khat* were estimated at 61.1% in a large survey of 2,500 people in Yemen. While 31.5% of Kenyan (Nairobi) school children reported use in 2011. In Kenya, a small survey found that *khat* was the third most common drug used after alcohol and tobacco. In Kenya, urban *khat* consumption is strongly associated with poverty. Among 90 juveniles attending court in Nairobi, it was the fifth most common drug, with 5.6% of respondents reporting use. Similarly, a study sampling 181 adults in Uganda found 31.5% lifetime *khat* use and 20.4% current users, and there was a correlation between *khat* use and tobacco smoking (Kinyanjui and Atwoli, 2013).

iii) Tobacco

According to the WHO (2007) report, about 1.9 billion people were smoking tobacco worldwide. It is a highly addictive substance spreading in the world in a way that cannot be controlled. People in developed countries are more affected than those who are in developing and underdeveloped countries. According to this report, tobacco is the second leading cause of death in both developed and developing countries. It will eventually kill one in two users and be responsible for the death of one in ten adults. In the world, 4.9 million deaths occur each year

because of smoking tobacco. If the current smoking pattern continues, it is estimated that it will cause 10 million deaths each year by 2020 (WHO, 2007).

In the Nigerian prison study, nicotine is the most frequently used (22.9%) (Williams *et al.* 2005). While in western Kenya in Eldoret prison, the prevalence of cigarette use was 32.7%, while 22.5% admitted to chewing tobacco (Kinyanjui and Atwoli, 2013). In a study in Lithuanian prisons (Narkauskaitė *et al.* 2007), 85.3% of the prisoners smoke tobacco. In the Bangalore Prison study (Math *et al.* 2011), 67.3% of the prison population reported they used tobacco in some form in their lives. This is more than double the tobacco use prevalence in Karnataka (29.6%-figure for 2001). 60.2% reported ever smoking tobacco, and 14% ever chewing tobacco. 97% of those who smoked or chewed tobacco had been using tobacco in the year before prison entry. Among new male entrants into the prison institution, 74.3% reported using tobacco, and 71.9% reported using tobacco during the month before they were imprisoned. Even though there are few studies conducted on the prevalence of tobacco use in prison settings, the available data indicate that most prisoners in America smoke (Bobak *et al.* 2000).

iv) Cannabis

Among different illegal drugs, cannabis is one of the most widely used in the world. Cannabis can cause behavioral problems with excessive use and precipitate psychosis in vulnerable individuals. Cannabis intoxication mimics a psychotic disorder with predominant changes in emotion, excitement, and hallucinatory experiences. Long-term cannabis use is associated with a motivational state (Lukasiewicz *et al.* 2007).

In a Nigerian prison, according to Williams *et al*. (2008), lifetime use of any substance among the prison population was 85.5%. 27.7% of prisoners reported current drug use, and dependent use was estimated to be 12.5%. Whereas, according to the study conducted in western Kenya in Eldoret prison, the prevalence of cannabis use was 21%, and among prisoners in Uganda prevalence of marijuana was (49%) (Kinyanjui and Atwoli, 2013). Cannabis was the most frequently reported illegal drug, with lifetime prevalence rates among prisoners of 11–86% in prisons in the European Union countries (EMCDDA, 2003). Marijuana or hashish was the most common drug prisoners used in the month before their imprisonment. In Poland in 2001, almost 20% of the prisoners were using drugs like marihuana, hashish, and amphetamine.

However, it is less than the Irish custody, in which 48% had an indicator of a drug problem (Carns *et al.* 2007).

2.3.Recidivism and Antisocial Personality Disorder

Studies have shown that offenders who meet psychopathic or antisocial personality disorder criteria have greater criminal behaviors, commit more violent types of crimes, and are more likely to recidivate than non-psychopathic offenders. (Anton *et al.* 2012). A study conducted on convicted individuals who were diagnosed with ASPD indicates that 42% of male participants were recidivists. Whereas, female participants' rate of recidivism was 12.6%. Young ages, male gender, antisocial personality disorder, and bad life conditions are other known risk factors for recidivism (Hakansson and Berglund, 2012). A follow-up study of 64 prisoners diagnosed with ASPD in prison for 5 years indicates that 39% of those prisoners were re-arrested later by committing violent crimes. Similarly, according to the study conducted by Donald *et al*. (2011), ASPD was present in 113 subjects (35.3%). Offenders with ASPD were young, had higher rates of substance use, anxiety, mood disorder, psychotic disorders, somatoform disorders, borderline personality disorder, and ADHD, and had a higher suicide risk. Their quality of life was poor, and their Level of Service Inventory-Revised (LSI-R) scores were higher, indicating a greater risk for recidivism (Donald *et al.* 2011).

A study conducted in Grendon on 244 offenders, released from prison who had personality disorders, revealed that 33.2% of the offenders who were released after staying 2 years in prison committed crimes again. Recidivism rates in the following 3 years after release were 20% for those who took therapy for more than 18 months and 40% for those who took therapy for 18 months or less (Lee, 2001).

In Holland, a longitudinal study was conducted about the recidivism of those who were diagnosed with antisocial personality disorder. 52% of 517 participants, who were discharged from the hospital between the years of 1955 and 1980, re-committed a crime in the next five years. A study shows that individuals with antisocial personality disorder were more recidivist than people who had other types of mental disorders (Lee, 2001).

2.4.Recidivism and Substance Abuse

According to Belenko (2002), prisoners who regularly use drugs or alcohol have higher recidivism rates than other prisoners. Also, as it is possible to understand from National inmate

survey data, already noted earlier, the more likely that the inmate is a regular drug user (Belenko, 2002a). Within 3 years, about 95% of released state inmates with drug use histories return to drug use (Martin *et al.* 1999), 68% are rearrested, 47% are reconvicted, and 25% are sentenced to prison for a new crime (Langan and Levin, 2002).

Spohn (2007) examined the recidivism rates of drug and nondrug offenders to determine if incarceration affected the likelihood of recidivism, severity of recidivism, and time until recidivism. She found that those who were incarcerated had higher recidivism rates and shorter times until reoffending than those who were not incarcerated. This finding held across both drug and nondrug offenders and across offenders with few stakes in conformity and those with high stakes in conformity. Using the same data, Spohn and Holleran (2002) also found that drug offenders had the shortest time to recidivate and had the highest likelihood of recidivating.

Among Irish custody, 48% had an indicator of a drug problem, and 62% of the offenders with a drug problem were re-arrested in the first three years after release, compared to 57% of those without. And 57% had new convictions in the first three years, compared to 53% of those without a drug Problem (Carns *et al.* 2007).

Drug-using individuals are more likely to re-offend, with differential probabilities depending on drug type and frequency of use (Makkai *et al.,* 2004; Putnins, 2003; Salmenainen, 1995; Stevenson and Forsythe, 1998). Similarly, prisoners with lower educational attainment are more likely to re-offend (Prichard and Payne, 2005; Salmelainen, 1995).

Gendreau *et al.* (1996) conducted a meta-analytic review that examined the predictors of adult criminal recidivism. They reported that having a substance abuse problem was only mildly related to recidivism (Mz+=. l0). More importantly, when compared individually with other dynamic factors such as antisocial personality (Mz+= .18), criminal companions (Mz’ = .2 l), criminogenic needs (e.g., employment, education, and criminal attitudes) (Mz+ = .18), and interpersonal conflict (Mz+ = .12), substance abuse demonstrated the smallest relationship with recidivism.

According to Renauer and Henning (2005), the study found there were no gender differences in the likelihood of involvement in a future police report of domestic violence, either as a victim or a suspect. However, Dannerbeck and Yan's (2009) findings of the logistic regression analysis for the juvenile offenders indicated that Male offenders had greater odds of being recidivists than

female offenders. A meta-analysis by Bonta *et al.* (1998) shows that drug abuse (Mz+= .09) yielded a slightly stronger relationship with general recidivism than did alcohol abuse (Mz+= .06).

3. Research Methods and Materials

To assess the contributions of antisocial personality disorder (ASPD) and substance abuse (SA) to recidivism, a survey method of a quantitative research approach was applied. Accordingly, to estimate the prevalence of recidivism, substance abuse problems, and antisocial personality disorder of the offenders, a descriptive research design was utilized. To understand the relationship between recidivism and substance abuse problems, recidivism and antisocial personality disorder, as well as recidivism and socio-demographic characteristics correlational research design was utilized.

3.1.Study Setting, Target Population, Sample, and Sampling Techniques

West Arsi Zone Correctional Administration Office is found in Oromia National Regional State in Shashamene town, which is 254 km from Addis Ababa to the south. The target population of the study was 1,550 males and 52 females, a total of 1,602 offenders of the West Arsi Zone Correctional Administration Office, who got an equal chance of being involved in the sample of the study. Out of the 1,602-target population, samples of 310 offenders of the correctional administration office were selected, and they participated in the study by using a systematic random sampling technique. The sample size was determined using Krejcie and Morgan's (1970) formula for sample size determination. The scientific sample size was calculated with a 95% confidence level and 5% degree of precision.

3.2.Tools and Procedures of Data Collection

To collect data about the respondents' socio-demographic characteristics and criminal behaviours, including recidivism, 12 fully structured closed-ended questions were developed and employed in the study. The CAGE questionnaire is an instrument that was used to collect data about the substance abuse problems of the respondents. Additionally, to collect data about the respondent's antisocial personality disorder, Mini International Neuropsychiatric Interview (M.I.N.I.) 5.0.0 English version sub-scale was employed. Both instruments were applied after being adopted and translated into the Afaan Oromo and Amharic languages. Validity and reliability studies were conducted for the instruments.

To fulfil the procedure of data collection, the researcher took a letter of cooperation from the concerned body. With the letter, the researcher went to the West Arsi Zone Correctional Administration Office to get permission from the officials to conduct the study. Firstly, the objectives and significance of the study were presented to the correctional administration officials. Then, they allowed me to conduct the study. Again, the researcher discussed the objectives and significance of the study with randomly selected participants, and they were informed that participation in the study was only based on their interest, as participating in the study did not harm them, and other necessary issues were discussed in detail with the participants. The data was collected through face-to-face interviews by the researcher and two psychologists working in the correctional office after a brief orientation about the study.

4. Methods of Data Analysis

The data collected to estimate the prevalence of recidivism was analysed by counting and converting to a percentage the frequencies of the responses to the questionnaire that was developed to assess whether they were imprisoned two or more times or not. Antisocial personality disorder and substance abuse were also analysed by counting the number of respondents who met the criteria prepared to assess those issues. To estimate the contributions of socio-demographic characteristics of respondents: age, gender, educational level, marital status, place of residence, occupation, and types of crime to the dependent variable (recidivism), cross-tabulation and chi-square tests were used as well as to understand the direction and strength of the relationship, phi and Cramer's V were employed; in which for those variables whose degrees of freedom are 1 phi value was accepted; whereas, for those variables whose degrees of freedom are greater than 1, Cramer's v value was accepted. Finally, to examine the contributions of ASPD and substance abuse (alcohol, *khat*, tobacco, and hashish abuse) to recidivism, the binary logistic regression model was employed. The overall analysis was done by using the SPSS 20 version.

5. Results and Discussion

This section focuses on examining the results intended to provide answers to the research questions raised. The data, which were collected from a total of 310 offenders of the West Arsi Zone Correctional Administration, were analysed as follows.

5.1.Socio-demographic Characteristics of Respondents

The total number of offenders who participated in the study was 310. Among the total

Table 1: Socio-demographic characteristics of respondents in the West Arsi Zone Prison, 2015

Variables	Male	Female	Total
Age			
18-25	121	17	138(44.5%)
26-40	110	2	112(36.1%)
41-60	36	0	36(11.6%)
>60	19	5	24(7.7%)
Total	286(92.3%)	24(7.7%)	310(100%)
Marital Status			
Single	116	10	126(40.6%)
Married	140	12	152(49%)
Widowed	2	0	2(0.6%)
Divorced	20	2	22(7.1%)
Separated	8	0	8(2.6%)
Total	286(92.3%)	24(7.7%)	310(100%)
Educational level			
Illiterate	38	9	47(15.2%)
Grade 1-8	145	9	154(49.7%)
Grade 9-12	86	6	92(29.7%)
Diploma & above	17	0	17(5.5%)
Total	286(92.3%)	24(7.7%)	310(100%)
Place of Residence			
Urban	129	13	142(45.8%)
Rural	157	11	168(54.2%)
Total	286(92.3%)	24(7.7%)	310(100%)
Occupation			
Farmer	114	6	120(38.7%)
Daily labourer	56	9	65(21%)
Merchant	44	2	46(14.8%)
Unemployed	18	2	20(6.5%)
Gov/ Employee	31	0	31(10%)
Others	23	5	28(9%)
Total	286(92.3%)	24(7.7%)	310(100%)

Participants, 286 (92.3%) of them were male, the remaining 24 (7.7%) were female. The majority of the offenders - 138-(44.5%), were found in the emerging adulthood age category, i.e., 18-25 years, 112 (36.1%) were found in early/young adulthood age (26-40), and late adulthood

(>60 years) accounted for 24 (7.7%). Out of the total 24 female offenders, the majority, 70.8% (17) of them, were found in their emerging adulthood years. Out of the total participants, 154 (49.7%) of the offenders' educational level were primary, i.e., grade 1-8, 92 (29.7%) were grade 9-12, 47 (15.2%) did not have formal education, and offenders who had an educational level of diploma and above accounted for 17 (5.5%). Similarly, most of the offenders were married and accounted for 152 (49%); 126 (40.6%) were single. Furthermore, most of the offenders were from rural area sand accounted for 168 (54.2%), whereas the remaining 142 (45.8%) were from urban areas. Similarly, many offenders 'occupation before their imprisonment was farming, and they accounted for 120 (38.7%); 65 (21%) were daily labourers, and 20 (6.5%) of them were unemployed.

i) Recidivism and Antisocial Personality Disorder

The findings of the study revealed that the prevalence of recidivism among the offenders was 21.6%. This result is less than the finding of the study conducted by Abrifor *et al.* (2011), in which in Nigeria the prevalence of recidivism was 35% in 2007, 44% in 2008, and 52.4% in 2010. However, the prevalence of recidivism in this study was greater than the prevalence of recidivism in community service in Kampala district alone, i.e., 12%, and at the national level of Uganda, 6% (Ssebuggwawo, 2010).

The finding of the study indicates that the prevalence of antisocial personality disorder among offenders of the West Arsi Zone Correctional Administration Office was 38.4%. This result is greater than the study conducted by Sonja & Dap (2011) in a sample of 500 South African male offenders, in which the prevalence of ASPD was 17% and 12% in Arroyo and Ortega (2009). However, it was less than the findings of Black and Larsen (2000), in which ASPD prevalence was reported in almost 80% of men and 65% of women in U.S. prisons, (Langeveld and Melhus, 2004) 60%, and in a systematic review of 62 surveys, the prevalence of antisocial personality disorder was 47%.

ii) Prevalence of Substance Use and Abuses

a) Alcohol Use and Abuses

The findings of the study indicate that the prevalence of alcohol use among prisoners of the West Arsi Zone Correctional Administration Office before their imprisonment was 48.1%. Whereas the prevalence of alcohol abuse among the general prison population was 40%. The prevalence

of alcohol abuse among recidivists was 89.6%, which is more than double the prevalence of alcohol abuse in general offenders of the Correctional Administration Office, which was 40%. This finding is greater than the Irish custody in which 62% of offenders with an alcohol problem in 1999 were re-arrested during the first three years after being released (Carns *et al.* 2007). In contrast to this finding, the prevalence of alcohol abuse among Uganda's offenders accounts for only 2% (Kinyanjui and Atwoli, 2013).

b) Khat Uses and Abuses.

The findings from the study show that the prevalence of *khat* use among the offenders of the West Arsi Zone Correctional Administration was 53.9%. The study also reveals that the prevalence of *khat* abuse among the offenders was 37.4%. This prevalence is less than the finding of Kinyanjui and Atwoli (2013), in which the prevalence of *khat* abuse was 17% among the Ugandan prisoners. Furthermore, the prevalence of *khat* abuse among recidivists of West Arsi Zone Correctional Administration was 77.6%, which is greater than the double prevalence of *khat* abuse among general offenders, which was 37.4%.

c) Tobacco Use and Abuse

The findings of the study show that the prevalence of tobacco use among offenders of the West Arsi Zone Correctional Administration was 47.4%. This finding is greater than the finding of Williams, et *al.* (2008), a study conducted in Nigerian Prisons that accounts for 22.9% and 32.7% of cigarette use & 22.5% of chewing tobacco in Western Kenya, Eldoret prison. In contrast, it is almost less than half the prevalence of the Uganda prisoners, in which the prevalence of cigarettes/tobacco was 90% (Kinyanjui and Atwoli, 2013). Similarly, it is also less than the findings of the study conducted by Narkauskaitė *et al.* (2007), in Lithuanian prisons, 85.3%, of the Bangalore Prison study (Math *et al.* 2011), 67.3%, whereas 33.2% of offenders of West Arsi Zone Correctional Administration were abusing tobacco. Furthermore, the prevalence of tobacco abuse among recidivists was 65.7%, which is almost double the prevalence of tobacco abuse among the general offenders of the West Arsi Zone Correctional Administration office, which was 33.2%.

d) Hashish Use and Abuse

The prevalence of hashish use among the offenders of the West Arsi Zone Correctional Administration was 29.7%. This prevalence is greater than the prevalence of cannabis use in

Western Kenya, Elbore Prison, i.e., 21%, and it is greater than the finding of the study conducted in Poland in 2001, which showed that almost 20% of the prisoners were using drugs like marihuana, hashish, and amphetamine. However, it is less than the finding of Kinyanjui and Atwoli (2013), in which the drug use among prisoners in Uganda was 65%. Furthermore, the study findings also reveal that the prevalence of hashish abuse among offenders of the West Arsi Zone Correctional Administration Office was 28.1%. According to a review of studies analysed by Fazel *et al.* (2006) that reviewed thirteen studies with 7,563 offenders who met the review criteria, the prevalence of drug abuse and dependence varied from 10% to 48% in male offenders and 30% to 60% in female offenders. Moreover, the study also shows that the prevalence of hashish abuse among recidivists of the West Arsi Zone Correctional Administration office was 86.6%, which was more than three times the prevalence of hashish abuse among the general offenders of the West Arsi Zone Correctional Administration Office, which was 28.1%.

5.2.Association Between Recidivism & Socio-Demographic Characteristics

i) Recidivism and the Age of Respondents

A Pearson chi-square test result shows that there is a significant relationship between recidivism and the age of respondents (X^2= 10.917, df = 3, n 310, p=.012). Accordingly, a larger proportion of offenders from the emerging adulthood age category are more recidivists than other age categories. In addition to this, Cramer's V value shows that recidivism and age have a positive but weak relationship. This result shows that as the age of respondents increases, recidivism also increases. This direct relationship between the age of respondents and recidivism is a result of recidivists found in emerging adulthood, which was 21.6%, whereas, among young adulthood age categories, the prevalence was 25.6%. Only these two age categories contain 94% of the recidivists. This is supported by the study conducted by Piquero *et al.* (2015), in which age is significantly related to violent recidivism. The random effect size for the influence of age on violent recidivism was −0.026 (95% CI [−.049, −.003], p = .029), indicating that lower age was associated with the increased rate of violent recidivism.

ii) Recidivism and Gender

In this study, Pearson's chi-square test results revealed that there is no significant relationship between recidivism and gender. The Phi value, which indicates the strength of the association between the two variables, shows that recidivism and gender have a negative and weak

relationship. This finding is supported by the study of Renauer and Henning (2005), in which there were no gender differences in the likelihood of involvement in a future police report of domestic violence, either as a victim or a suspect. In contrast to the finding, gender was statistically significant as a determinant influencing recidivism among inmates in the Nigerian Prisons (Abrifor *et al.* 2011).

iii) Recidivism and Educational Level

Regarding the association between recidivism and educational level, Pearson's chi-square test results revealed that there is no significant relationship between the two variables. In addition to this, Cramer's V value shows that recidivism and educational level have a positive but weak relationship. This finding is supported by the study conducted by Katsiyannis *et al.* (2004) in which individual differences in educational achievement were not predictive of recidivism. However, in contrast with this result, the study findings of Prichard & Payne (2005) and Salmelainen (1995) show that recidivism and the educational level of offenders had a significant relationship, in which offenders with lower educational attainment are more likely to re-offend (Prichard and Payne, 2005; Salmelainen, 1995).

iv) Recidivism and Marital Status

A Pearson chi-square test results show that there is a significant relationship between recidivism and marital status (X^2=17.802, df = 2, n=310, p=.000). Significantly, larger proportions of offenders who had a single marital status (55.2%) were more recidivists than married (26.9%), and others who were widowed, divorced, and separated account 17.9%. Similarly, Cramer's V value, which indicates the strength of the association between the variables, is .240, which shows that recidivism and marital status have a positive and weak relationship. This result is supported by the study conducted by Abrifor *et al.* (2011), in which marital status was statistically significant as a determinant of recidivism among inmates in the Nigerian prisons. Accordingly, non-married offenders were more recidivistic than other marital statuses (Abrifor *et al.* 2011).

v) Recidivism and Place of Residence

A Pearson chi-square test result shows that there is a significant relationship between recidivism and place of residence (X^2= 9.811, df= 1, n=310, p=.002). Significantly, larger proportions of offenders from urban places of residence (62.7%) are more recidivists than offenders from rural areas (37.3%). Similarly, the Phi value, which indicates the strength of the association between

the two variables, is -.178, which shows that recidivism and place of residence have a negative and weak relationship. The negative relationship between recidivism and place of residence is a result of most of the offenders being from rural areas; however, the prevalence of recidivism was high among offenders from urban areas. This finding is supported by Staton-Tindall *et al.* (2015), in which place of residence significantly predicts recidivism; accordingly, individuals in urban areas were 2.4 times more likely to be recidivists than rural individuals.

vi) Recidivism and Employment

Regarding the association between recidivism and employment, Pearson's chi-square test results revealed that there is no significant relationship between the two variables. In addition to this, the Phi value indicates that the strength of the association between the two variables is a negative and weak relationship. This finding is supported by Turner and Petersilia (1996), whose evaluation of a work release program found that employed offenders were not significantly less likely to be recidivists than unemployed offenders. In addition to this, Tripodi *et al*. (2010) study findings show that obtaining employment when released from correctional institutions did not significantly decrease the likelihood of reincarceration over time (Ibid). However, most criminological research indicates a strong inverse relationship between employment and crime, suggesting that ex-offenders who obtain employment are at significantly reduced risk for reoffending (Laub and Sampson, 2003; Sampson and Laub, 1993).

5.3.Recidivism and Antisocial Personality Disorder

Antisocial personality disorder significantly contributed to recidivism in the logistic regression model. Accordingly, offenders who met the criteria of ASPD were re-imprisoned more times than offenders who did not meet the criteria. This result is supported by the study conducted by Anton *et al.* (2012) in which offenders who have psychopathic or antisocial personality disorder criteria have greater criminal behaviours, commit more violent types of crimes, and have a higher chance of recidivism than non-psychopathic offenders.

5.4.Recidivism and Substance Abuse

Table 2: Logistic regression predicting recidivism

Variable	B	S.E.	P	Odds Ratio	95% C.I. for EXP(B)	
					Lower	Upper
ASPD (1)	2.274	.508	.000	9.715	3.590	26.289

Alcohol Abuse (1)	.969	.657	.140	2.636	.728	9.547
Khat **Abuse (1)**	-.625	.648	.335	.535	.150	1.907
Tobacco Abuse (1)	.321	.531	.545	1.379	.487	3.900
Hashish Abuse (1)	2.757	.558	.000	15.747	5.276	46.996
Constant	-4.396	.526	.000	.012		

-2 Log likelihood = 155.747, Cox & Snell R Square = .418, Nagelkerke R Square= .645

As it is possible to understand from the results of the logistic regression model (Table 2), alcohol abuse, *khat* abuse, and tobacco abuse were non-significant to the model. However, hashish abuse has significantly contributed to recidivism. Accordingly, offenders who met the criteria of hashish abuse were re-imprisoned more times than offenders who did not abuse hashish. Several study findings are in support of this result. For instance, a meta-analysis by Bonta *et al.* (1998) reported that drug abuse had a slightly stronger relationship with general recidivism than did alcohol abuse. Similarly, according to the findings of Makkai *et al.* (2004), Putnins (2003), Salmenainen (1995), and Stevenson and Forsythe (1998), drug-using individuals are more likely to re-offend, with differential probabilities depending on drug type and frequency of use. Also, Belenko (2002) concludes that offenders who regularly use hashish have higher recidivism rates than other prisoners (Belenko, 2002). In contrast to the findings of this study, according to Castillo and Alarid (2011), alcohol was the most powerful predictor of recidivism, more than any other substance or any other demographic variable. Accordingly, offenders with alcohol use problems were significantly more likely to commit a violent offense.

6. Conclusion and Recommendations

6.1.Conclusion

The prevalence of recidivism among offenders in the West Arsi Zone Correctional Administration Office was 21.6%; the prevalence was high among hashish abusers, emerging adulthood age categories, and offenders who met antisocial personality disorder criteria. Whereas the prevalence of antisocial personality disorder among the offenders was 38.4%. In addition to this, the prevalence of substance abuse was 34.7%, from which alcohol abuse was the most prevalent, followed by *khat* abuse; the prevalence of tobacco abuse and hashish abuse takes the third and fourth rank among offenders in the West Arsi Zone Correctional Administration Office.

A Pearson chi-square test revealed that the socio-demographic characteristics of offenders: age of respondents, marital status, and place of residence had significant relationships with recidivism. However, gender, educational level, and employment were not significantly

associated with recidivism. Moreover, Phi & Cramer's V value shows that the age of respondents, marital status, and educational level had a positive but weak relation with recidivism. Whereas, place of residence, gender, and employment had a negative and weak relationship with recidivism.

Regarding the contributions of antisocial personality disorder and substance abuse to recidivism, offenders who met the criteria of antisocial personality disorder were more recidivistic than offenders who did not meet ASPD criteria. Similarly, offenders who abuse hashish were also more recidivists than non-hashish abusers. Therefore, antisocial personality disorder and hashish abuse significantly contributed to recidivism.

6.2.Recommendations

Based on the stated research questions and the above-described findings, the following recommendations are made.

- ☞ Criminal recidivism is a complex problem that is a product of different psychological and social factors that affect the most productive forces in one's country. Therefore, the government and different stakeholders should focus on working on the prevention of criminal recidivism.
- ☞ Government stakeholders, including prison administrations, should be aware of the link between recidivism and antisocial personality disorder, as well as substance abuse, to collaborate on prevention efforts.
- ☞ Since the prevalence of recidivism was high among substance abusers, and hashish abuse had significantly contributed to recidivism, different concerned bodies should work on the prevention of substance abuse in different settings.
- ☞ For offenders with antisocial personality disorder, providing intervention that focuses on the self-interest of offenders, which means what the offender wants to get out of life, and working with them to develop the skills to get those things in a pro-social rather than antisocial way, is important. Similarly, cognitive-behavioural and social learning techniques are also the most frequently used methods for treating antisocial individuals. Teaching life skills and cognitive skills that are congruent with the offender's educational and developmental levels, and identifying and modifying cognitive distortions and

criminal lifestyle patterns of offenders with ASPD, is also important for intervention of the disorder, and it plays a great role in reducing recidivism.

- ☞ Alcohol and hashish abuse treatments should be provided by skilled professionals for those new entry offenders who were abusing alcohol and hashish before their imprisonment. Since alcohol and hashish-taking are not allowed in Ethiopia's correctional institution setting, the correctional administration, especially professionals like psychologists, should focus on relapse prevention of alcohol and hashish use after they are released from correctional institutions.
- ☞ Therapeutic communities are best for tobacco treatment since using tobacco is not forbidden in Ethiopia's correctional institutions. Therefore, if resources and places are available, it is effective to treat those offenders who abuse tobacco separately from the rest of the offenders until they complete the intervention programs. Similarly, like the treatment of other substance abuse, it is also important to focus on relapse prevention when treating tobacco abuse.
- ☞ Since *khat* use is not permitted in most of the country's correctional settings, its treatment should focus on offenders who were abusing it before their imprisonment. Also, working on relapse prevention is important for their life after prison. But in those few correctional settings in which *khat* use is allowed, treatment should be provided for those offenders who are abusing it.
- ☞ The researcher also recommends that other interested researchers conduct more studies on these issues.

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