Original Research Article

An Examination of Micro-Irrigation Potentials on Vegetable Farms in Lesotho: A Comparative Benefit-Cost Approach

ABSTRACT

Aims: The study evaluated the costs-benefits and socio-environmental effects of drip and sprinkler micro-irrigation technologies by small-scale vegetable farmers in Butha-Buthe and Leribe districts in Lesotho. The motivation for the study was based on the premise that Lesotho remains challenged by food insecurity despite being endowed with extensive water resources.

Study design: The study used quantitative research design which further involved the use of non-experimental survey research design.

Place and Duration of Study: The study was conducted in Butha-Buthe and Leribe districts of Lesotho

Methodology: A multi-stage sampling technique was used to select 155 representative samples of vegetable farmers from the two districts. A structured questionnaire was used to obtain primary data on the socio-economic characteristics of the representative farmers, various impacts of the use of irrigation technologies, and the investment costs on fixed and variable costs, as well as returns, which were also obtained from a sample frame. Net Present Value (NPV) and Internal Rate of Return (IRR) were used to evaluate the two irrigation methods.

Results: Results showed that vegetable farmers in the Leribe district were more educated than their counterparts from the Butha-Buthe district. It was also revealed that the average age of the vegetable farmers in the Leribe district was 49 years. In comparison, the average age of vegetable farmers in the Butha-Buthe district was 50 years. The results of the comparative cost-benefit analysis concluded that the drip irrigation system is more viable than the sprinkler irrigation method.

Results of the Cost-Benefit Ratio of drip irrigation was 2.2 compared to 1.9 for sprinkler irrigation. The drip irrigation method yielded the highest NPV of M426, 961.93 in, while the sprinkler system provided a larger IRR of 63.8%. The two micro-irrigation systems studied passed the capital investment evaluation selection criteria, with both having a positive NPV and IRR.

Conclusion: Findings from the study showed that micro-irrigation usage resulted in increased productivity among the vegetable farmers.

Key words: Cost-benefits, micro-irrigation, vegetable-farms

1.INTRODUCTION

Agriculture, mainly produces livestock and crops and plays a significant role in Lesotho's economy. Lesotho is among the poorest countries in Southern Africa, with 57 per cent of the population living below the poverty line (World Bank, 2019). About 70 per cent of the population live in rural areas and depend on agriculture for their livelihoods. Most farmers are involved in the subsistence cultivation of cereals, where the country does not have a competitive advantage due to the agroclimatic conditions, small farm size, and lack of mechanisation (World Bank, 2019).

A significant factor in promoting the robust economic growth of Lesotho agriculture has been the horticulture industry, which produces fruits and vegetables (Bureau of Statistics, 2018). The vegetable farming usually requires more water (Bwire *et al*, 2024). According to Oladoyin *et al*, (2023), vegetable crops are grown in many parts of the world contributing significantly to income, security and the nutritive value of many households. In Lesotho, the Horticulture-Based Farming System, a component of the Agricultural Productivity Program for Southern Africa (APPSA), was introduced by Lesotho in 2021. The project aim is to produce highly valuable plant materials that can withstand drought and be commercially viable. Additionally, the project aims to facilitate technology transfer by fortifying institutional connections at both the local and national levels (World Bank, 2019). Irrigation is required because commercial horticulture presents significant potential to change Lesotho's rural economy and agricultural sector (Mtetwa, 2018). During the 2016–17 crop year, tomatoes accounted for 55.5% of the cultivated area in the second quarter, whereas cabbage covered 30.8% in the fourth quarter (Bureau of Statistics, 2018). According to the Bureau of Statistics (2018), the most harvested vegetables were cabbage, rape and tomato respectively in the 2016/2017 agricultural year.

Lesotho's primary natural resource is water. However, on some occasions, droughts have an impact on agricultural production, which causes the country to request aid from abroad and significantly reduces its GDP contribution (FAO, 2005). Mphahama (2011) states that there is one remaining option: to increase output through irrigation projects because there are few opportunities to expand food production through area expansion.

According to the Government of India (2015), irrigation is the deliberate application of water using artificial systems to fulfil the water needs of agriculture. According to Velasco-Munoz *et al*. (2019), sustainable micro-irrigation projects employ irrigation techniques that may adequately hydrate crops even when there is a restricted water supply without requiring a sizable energy input or substantial financial resources. The last 20 years have seen a much slower rate of sustainable irrigation development than anticipated for several reasons, including the degradation of irrigated crop land, improper management of irrigation schemes, challenges in maintaining and rehabilitating schemes, and issues encountered both upstream and downstream in the sharing of water resources (Mphahama, 2011).

According to the Government of India (2015), micro-irrigation is the gradual application of water above or below the soil surface through tiny streams, drops, or sprays. Compared to the traditional surface irrigation method, micro irrigation systems are crucial for reducing water consumption and increasing water efficiency. Additionally, micro-irrigation lowers soil erosion, undesirable plants (weeds) growth, and cultivation costs (The Government of India, 2015). Shallow soil areas and a variety of topographies can benefit from micro irrigation. Sprinkler and drip irrigation are two popular micro irrigation techniques in Lesotho.

Groundwater and surface water resources abound in Lesotho. The annual average rainfall is 760 mm, with variations of up to 1600 mm in the north-eastern highlands and 300 mm in the western lowlands (Ntai, 2011). Water is readily available, but distributing it is a big issue because of the terrain. The mountains have more water than other places but less agricultural land is there. Water is frequently found in valleys in lowland areas; it must be pumped to the arable grounds because it is somewhat below the level of agricultural lands (United Nations Statistics, 2004).

Cost-benefit analysis (CBA), which was initially created as an economic appraisal tool, is a method for assessing policies that place a monetary value on all of a project's or policy's effects on all members of society (Boardman *et al.*, 2018). CBA is typically applied before the project begins and is frequently used to determine whether to implement projects or to choose between many possibilities. It can also be used for monitoring and evaluation during project implementation and at the end of the project. This study applied the principle to existing irrigation projects in the study areas in Lesotho.

Numerous obstacles keep Lesotho's agricultural production from reaching its productive potential for productivity. Low investment in irrigation projects, limited access to financing, and a lack of specialised skills are the main obstacles impeding the growth and development of agriculture. The World Bank (2019) states that severe climate risks combined with weak links in the value chain further impede agricultural growth.

Climate change presents small-scale farmers with many obstacles, including limited ability to use climate-smart farming practices that could increase agricultural productivity and reduce poverty. Global warming leads to changes in the climate that cause frequent droughts and other weather shocks, quickly deplete food supplies and cause financial losses. Families underinvest in high-yielding income-generating ventures and frequently turn to selling cattle and other productive assets (Cai *et al*., 2016). This has made Lesotho increasingly reliant on food imports due to climate change unless efforts are taken to address mainstream climate change issues in agriculture. The sector's productivity potential is threatened by irregular weather patterns, land degradation, and severe weather patterns (Dejene *et al.*, 2011).

Despite research showing that irrigation is essential for reducing the risks associated with climate change and boosting output, Lesotho has an abundance of water resources that are not completely utilised to support more micro-irrigation farming activities. Nearly all smallholder farming in Lesotho is rain-fed, and less than 1% of crop production is under irrigation, according to the World Bank (2019). Lesotho's estimated irrigable land area 2014 was 25,000 hectares (ha), or 0.05% of the country's 2.3 million ha of agricultural land. Despite the abundance of water resources and the highlands' enormous potential for water supply, the nation's irrigation still lags (World Bank, 2019).

The economic and social significance of sustainable irrigation projects cannot be overstated. However, the costs and advantages of various irrigation techniques have not yet been thoroughly examined in the target research region (the districts of Leribe and Butha Buthe), where there is significant irrigation potential. In light of this, this study conducted a comparative costs and benefits analysis of sustainable micro-irrigation projects in the Lesotho districts of Leribe and Butha Buthe.

The study's main objective was to comparatively analyse the costs and benefits associated with sustainable micro-irrigation projects in the Leribe and Butha Buthe districts of Lesotho.

The specific objectives were to:

- Describe different types of irrigation technologies used in the study area.
- Quantify the costs and benefits of irrigated vegetable production.
- Assess the gains of using micro-irrigation technologies in the study area.

2. MATERIALS AND METHODS

2.1 Research Design

The study used a descriptive quantitative research design and cross-sectional data was obtained and analysed.

2.2 Description of the Study Area

The study was conducted in two (2) out of the ten (10) districts of Lesotho: Leribe and Butha Buthe. Leribe has a population of approximately 337,521 while Butha Buthe has a population of 118,242 (Bureau of Statistics (BOS) 2016). Leribe has a land size of 837.1 km^2 while Butha Buthe has a land size of 581.3 km^2. Due to Leribe soil types, the first irrigation scheme in Lesotho was erected at Thaba Phatsoa in 1962, followed by the Leshoele irrigation scheme in 1968 (Ntai, 2011). The two districts covered during the study are shown in Figure 1 below.

Map 1: Map of Lesotho (Created with paintmaps.com, 2023)

2.3 Sampling Technique

A multi-stage sampling technique was used to select the respondents from the list of micro-irrigation user farmers obtained from the Department of Irrigation under the Ministry of Agriculture and Food Security. Firstly, purposive sampling was adopted to select the study area of the Leribe and Butha Buthe districts. The same sampling method was used to select two wards in each district in the second stage. Lastly, a simple random sampling technique was used to select 90 smallholder micro-irrigation user farmers from Leribe and 65 smallholder micro-irrigation user farmers from Butha Buthe districts, respectively.

2.4 Sample Size

A total of 155 farmers were selected from the two districts comprising 90 and 65 smallholder vegetable farmers who were micro-irrigation users from the Leribe and Butha Buthe districts.

2.5 Data Collection

The data used for the study were obtained during the 2022/2023 cropping season. The primary data for the study were obtained through a questionnaire complemented by oral discussions with the respondents' farmers. Secondary data were obtained from District Irrigation Offices from the Leribe and Butha Buthe districts and the Lesotho Bureau of Statistics Reports.

2.6 Methods of Data Analysis

Net Present Value (NPV) and Internal Rate Return (IRR) investment decision tools helped to determine the viability of different irrigation techniques. The social and environmental costs and benefits were analysed quantitatively based on the responses.

2.6.1 Net Present Value (NPV)

The Net Present Value framework was used to determine the viability of the irrigation investment options. The two irrigation systems expected net cash flows were discounted to present value and compared against the initial investment cost. A positive NPV signifies a feasible investment; when the NPV is negative the project is not viable (Boardman *et al*, 2018).

The selection of the appropriate discount rate is critical (Zizlavsky, 2014). For the study, the discount factor was presumed to be the cost of capital that equates to the Central Bank of Lesotho's premium lending rate of 7.75% in July 2023. The future cash inflows and out flows for the irrigation systems were based on the current revenue and costs of the irrigation methods and the estimated annual growth rates provided by the small-scale farmers. Based on the information from small-scale farmers, the annual net cash inflow is expected to grow by 5% over 5 years. The expected cost and benefits growth rate was determined by considering the Lesotho Inflation rate of 6. 9% as of May 2023 (BOS, 2023). The Net Present Value computational formulae:

$$NPV = \sum[(B_t - C_t) \,/\, (1 + r)^t] \quad \text{Equation 1}$$

Where Bt = Total Benefits in year t, Ct is Total Costs in year t, r = Discount rate,

(1+r) t = Discount factor for year t

2.6.2 Internal Rate of Return (IRR)

The Internal Rate of Return (IRR) is an evaluation index to measure long-term investment income. The IRR can also be described as the growth rate of an investment, which is comparable to the opportunity cost of capital or the borrowing rate of financing the project (Boardman et al., 2018). When the IRR exceeds the discount rate, the investment is accepted (Zizlavsky, 2014). The IRR was generated in Microsoft Excel using the IRR financial function. Without Excel, IRR could also be calculated manually using the following formula which is more of a trial-and-error method (FAO, 2005).

$$IRR = ldr + \frac{(hdr - ldr) \times NPV \text{ at } ldr}{(NPV \text{ at } ldr - NPV \text{ at } hdr)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ Equation 2}$$

where:

IRR = Internal Rate of Return

hdr = higher discount rate

ldr = lower discount rate

NPV = Net Present Value

3. RESULTS AND DISCUSSION

3.1 Farmers Age

The given data represents the distribution of individuals across different age groups. Tables 1 and 2 show the frequency and percentage of individuals in each age group, and the cumulative percentage.

Table 1: Leribe Farmers' Age

Age	Frequency	Percent	Valid Percent	Cumulative Percent
35-39 years	12	13.3	13.3	13.3

	40-44 years	21	23.3	23.3	36.7
	45-49 years	19	21.1	21.1	57.8
	50-54 years	12	13.3	13.3	71.1
	55-59 years	11	12.2	12.2	83.3
	60-64 years	7	7.8	7.8	91.1
	65-69 years	6	6.7	6.7	97.8
	+70 years	2	2.2	2.2	100.0
	Total	90	100.0	100.0	

Source: Computed from the Field Survey Data, 2023

According to Table 1, the 40-44 age group accounts for 23.3% of the respondents. This is followed by the 45-49 years age group, which accounts for 21.1%. The age group of +70 years accounts for 2.2% and is the lowest. From the collected data, the maximum age was 72, the minimum age was 34, the average age was 49, and the standard deviation was 9.33.

Table 2: Butha Buthe Farmers' Age

	Age	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	35-39 years	8	12.3	12.3	12.3
	40-44 years	14	21.5	21.5	33.8
	45-49 years	15	23.1	23.1	56.9
	50-54 years	8	12.3	12.3	69.2
	55-59 years	7	10.8	10.8	80.0
	60-64 years	5	7.7	7.7	87.7
	65-69 years	5	7.7	7.7	95.4
	+70 years	3	4.6	4.6	100.0
	Total	65	100.0	100.0	

Source: Computed from the Field Survey Data, 2023

Based on Table 2 above, 23.1 % of the participants were between 45 and 49 years of age while 21.5% of participants were between 40 and 45. From the collected data, the maximum age was 79, the minimum age was 35, the average age was 50, and the standard deviation was 10.49. Based on Table 1 and Table 2, it can be concluded that the 40-45 age group and 45-49 age group are dominant for both Leribe and Butha Buthe. It can be deduced from these results that most farmers involved in irrigation for both districts were adults.

3.2 Level of Education

Farmers' level of education varies widely depending on factors such as location, cultural norms, and access to educational opportunities. In many developed countries, farmers often have a high level of education due to the availability of formal education systems and agricultural training programs (Oduro-Ofori et al, 2015). Education is a factor that can influence individuals in the decision-making processes. Farmers with a good educational background, mostly make better-informed decisions. According to Ntai (2011), farmers who have attained higher levels of education are more likely to adopt new technologies or practices.

Figure 1 below shows farmers' level of education in both districts.

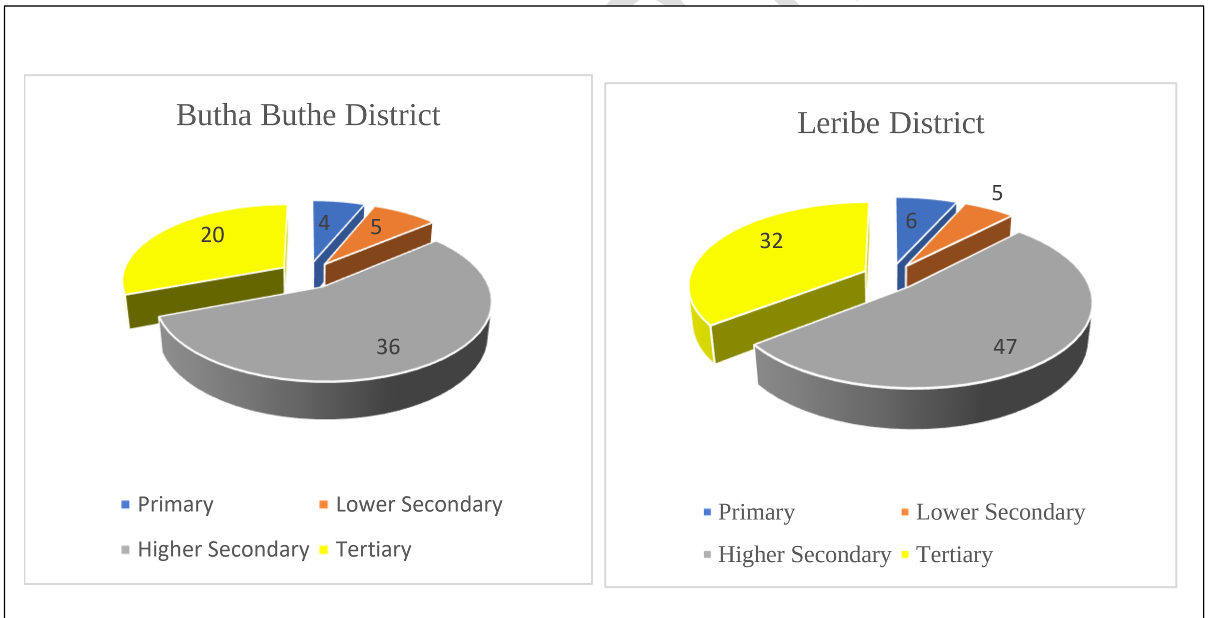

Figure 1: Farmers' Level of Education

Figure 1 shows that 47 (52%) Leribe famers had higher secondary school qualifications, while 36 (55%) Butha Buthe farmers had higher secondary school qualifications. On the other hand, Leribe has 32 (36%) farmers with tertiary qualifications, while Butha Buthe has 20 (31%) farmers with tertiary qualifications. As Ntai (2011) indicated, farmers who have attained higher levels of education are more likely to adopt new technologies or practices. Hence, irrigation technologies are highly adopted in the study area.

3.3 Irrigation Technologies

3.3.1 Drip and Sprinkler Irrigation

Drip irrigation and sprinkler irrigation are the two commonly used methods in agriculture for delivering water to plants. These irrigation techniques aim to provide water directly to the root zone of plants, ensuring efficient water use and minimising water loss through evaporation or runoff (Gibson, 2022). Table 3 below shows the frequency distribution of the two types of irrigation methods: drip irrigation and sprinkler irrigation. The table provide information on the number of occurrences (frequency) and the percentage of each type of irrigation method.

Table 3: Irrigation Technologies

Irrigation Types	Leribe		Butha Buthe	
	Frequency	Percent	Frequency	Percent
Drip Irrigation	61	67.8	42	64.6
Sprinkler Irrigation	29	32.2	23	35.4
Total	90	100	65	100

Source: Computed from the Field Survey Data, 2023

In Leribe district, drip irrigation is represented by a frequency of 61, which accounts for 67.8% of the population. Sprinkler irrigation, on the other hand, has a frequency of 29, representing 32.2% of the representative sampled farmers. It might be deduced from these results that drip irrigation technology was the most popular type of irrigation in the Leribe district.

In Butha Buthe district, drip irrigation is represented by a frequency of 42, which accounts for 64.6% of the population. Sprinkler irrigation, on the other hand, has a frequency of 23, representing 35.4% of the representative sampled farmers. It could also be seen from these results that drip irrigation technology was the most popular type of irrigation in Butha Buthe district. This might be due to the fact uneven and irregular surfaces can be easily irrigated using drip irrigation (Jayant *et al.*, 2022)

3.4 Net Present Value (NPV)

NPV is a financial metric used to determine the profitability of an investment by calculating the present value of expected cash flows discounted at a specified rate (Fernando, 2023). The drip

Irrigation NPV per hectare for the two districts shows the net present value (NPV) of cash flows for each year of the project. Tables 4 and 5 below, include the cash flow for each year, the discount rate applied (7.75%), and the present value calculated for each year. The present value of each cash flow is calculated by discounting it back to the present using the discount rate. The present value was calculated by multiplying the future cash flows by the annual discount factor. The sum of future cash flows was then deducted from the initial investment to determine the NPV of the irrigation methods.

Table 4: Leribe Drip Irrigation NPV/Hectare

Year	**Cash flow**	**Discount Rate (7.75%)**	**Present Value**
Year 0	-638, 553.88	1	-638, 553.88
Year 1	241, 639.78	0.9281	224, 265.88
Year 2	253,721.77	0.8613	218, 530.56
Year 3	266, 407.86	0.7994	212, 966.44
Year 4	279, 728.25	0.7419	207, 530.39
Year 5	293,714.66	0.6885	202, 222.55
Net Present Value			**426, 961.93**

Source: Computed from the Field Survey Data, 2023

To calculate the net present value (NPV), the initial investment was subtracted from the sum of all present values. Therefore, the net present value of the Leribe Drip Irrigation project per hectare is M426,961.93.

Table 5: Butha Buthe Drip Irrigation NPV/Hectare

Year	**Cash flow**	**Discount Rate (7.75%)**	**Present Value**
Year 0	-995, 706.64	1	-995, 706.64
Year 1	235, 195.22	0.9281	218, 284.68
Year 2	246, 954.98	0.8613	212, 702.33
Year 3	259, 302.73	0.7994	207, 286.60

Year 4	272, 267.87	0.7419	201, 995.53
Year 5	285, 881.26	0.6885	196, 829.25
Net Present Value			**41, 391.75**

Source: Computed from the Field Survey Data, 2023

To calculate the net present value (NPV), the initial investment was subtracted from the sum of all present values. Therefore, the net present value of the Butha Buthe Drip Irrigation project per hectare is M 41,391.75. Leribe drip irrigation NPV computations show that the return on investment is significantly higher than that for the Butha Buthe district, as shown in Tables 4 and 5 above. In summary, the cash flow analysis with discounted cash flows indicates that the Leribe drip irrigation has a positive NPV of M426,961.93. In contrast, Butha Buthe Drip irrigation has a positive NPV of M41,391.75. This suggests that the project's expected cash inflows, when discounted back to the present, exceed the initial cash outflow (Fernando, 2023).

3.4.1 Sprinkler Irrigation

The sprinkler Irrigation NPV per hectare shows the net present value (NPV) of cash flows for each year of the project. Table 6 and Table 7 include the cash flow for each year, the discount rate applied (7.75%), and the present value calculated for each year. The present value of each cash flow is calculated by discounting it back to the present using the discount rate.

Table 6: Leribe Sprinkler Irrigation NPV/Hectare

Year	**Cash flow**	**Discount Rate (7.75%)**	**Present Value**
Year 0	-320, 412.81	1	-320, 412.81
Year 1	211, 204.97	0.9281	196, 019.33
Year 2	221, 765.22	0.8613	191, 006.38
Year 3	232, 853.48	0.7994	186, 143.07
Year 4	244, 496.15	0.7419	181, 391.70
Year 5	256, 720.96	0.6885	176, 752.38
Net Present Value			**610, 900.05**

Source: Computed from the Field Survey Data, 2023

The Net Present Value of the Leribe Sprinkler Irrigation project is M610,900.05. The positive NPV indicates that the project is expected to generate a return higher than the discount rate used. Therefore, based on this analysis, the Leribe Sprinkler Irrigation project appears economically viable and profitable (Fernando, 2023).

Table 7: Butha Buthe Sprinkler Irrigation NPV/Hectare

Year	**Cash flow**	**Discount Rate (7.75%)**	**Present Value**
Year 0	-345, 504.94	1	-345, 504.94
Year 1	139, 183.79	0.9281	129, 176.48
Year 2	146, 142.98	0.8613	125 872.95
Year 3	153, 450.13	0.7994	122, 668.03
Year 4	161, 122.63	0.7419	119 536.88
Year 5	169, 178.77	0.6885	116, 479.58
Net Present Value			**268, 228.98**

Source: Computed from the Field Survey Data, 2023

The Net Present Value of the Butha Buthe Sprinkler Irrigation project is M268,228.89. In summary, the NPV analysis suggests that this sprinkler irrigation project in Butha Buthe has a positive NPV of M 268,228.98 per hectare at a discount rate of 7.75%. In contrast, Leribe has a positive NPV of M 610,900.05. This indicates that the project is expected to generate more cash inflows than outflows over its lifetime, making it a potentially profitable investment (Fernando, 2023).

3.5 Internal Rate of Return (IRR)

The internal rate of return (IRR) is a financial metric used to evaluate the profitability of an investment or project (Fernando, 2023). The IRR can also be described as the growth rate of an investment, which is comparable to the opportunity cost of capital or the borrowing rate of financing the project. It represents the discount rate at which the net present value (NPV) of cash flows from the investment becomes zero. When the IRR exceeds the discount rate, the investment is worthwhile (Fernando, 2023). The IRR was generated in Microsoft Excel using the IRR financial function to determine a discount rate with an NPV that is equal to zero or slightly below or above zero.

Table 8 represents the cash flow and present value calculations for a drip irrigation project in Leribe. The project's internal rate of return (IRR) per hectare is being evaluated over five years, with a discount rate of 28.05%. This discount factor gives an NPV which is slightly above or below zero.

Table 8: Leribe Drip Irrigation IRR/Hectare

Year	**Cash flow**	**Discount Rate (28%)**	**Present Value**	**Discount rate (29%)**	
Year 0	-638, 553.88	1	-638, 553.88	1	-638, 553.88
Year 1	214, 639.78	0.7813	167, 687.33	0.7752	166, 387.43
Year 2	253, 721.77	0.6104	154, 869.48	0.6009	152, 467.86
Year 3	266, 407.86	0.4768	127, 033.17	0.4658	124, 101.75
Year 4	279, 728.25	0.3725	104, 206.89	0.3611	101, 013.05
Year 5	293, 714.66	0.2910	85, 482.22	0.2799	82, 219.92
NPV			**715.20**		**12, 363.87**

Source: Computed from the Field Survey Data, 2023

$$IRR = ldr + (hdr - ldr)x[\text{NPV at } ldr \ / (NPV\ at\ ldr - NPV\ at\ hdr)]$$

IRR = 28+1[715.20/ (715.20+12, 363.87]

= 28 + 1 (0.05468)

= 28+ 0.05468

= 28.0547%

The Leribe drip irrigation IRR of 28.05% indicates that the project is viable since it exceeds the 7.75% cost of capital.

Table 9 represents the cash flow and present value calculations for a drip irrigation project in Butha Buthe. The project's internal rate of return (IRR) per hectare is 9.25%.

Table 9: Butha Buthe Drip Irrigation IRR/Hectare

Year	**Cash flow**	**Discount Rate (9%)**	**Present Value**	**Discount Rate (10%)**	**Present Value**

Year 0	-995, 706.64	1	-995, 706.64	1	-995, 706.64
Year 1	235, 195.22	0.9174	215, 775.43	0.9091	213.813.84
Year 2	246, 954.98	0.8417	207, 857.07	0.8264	204, 095.02
Year 3	259, 302.73	0.7722	200, 229.28	0.7513	194, 817.98
Year 4	272, 267.87	0.7084	192, 881.42	0.6830	185, 962.62
Year 5	285, 881.26	0.6499	185,803.20	0.6209	177, 509.77
NPV			**6,839.77**		**19,507.41**

Source: Computed from the Field Survey Data, 2023

IRR = 9+1[6, 839.77/ (6, 839.77+19, 507.41]

= 9 + 1 (0.2596)

= 9 + 0.2596

= 9.26%

The IRR for Leribe drip irrigation is 28.05%, while Butha Buthe is 9.26%. It can be concluded that these two investment decisions are profitable because the cost of capital (7.75%) is significantly lower than IRR values. The findings indicate that farmers operating drip irrigation systems in Leribe yield a higher investment rate than their counterparts in Butha Buthe district.

Table 10 represents the cash flow and present value calculations for the Sprinkler irrigation project in Leribe. The project's internal rate of return (IRR) per hectare is 63.8% which is the discount rate resulting in the NPV of future cash flows equal to zero or slightly above or below zero.

Table 10: Leribe Sprinkler IRR/Hectare

Year	**Cash flow**	**Discount Rate (63%)**	**Present Value**	**Discount Rate (64%)**	**Present Value**
Year 0	-320, 412.81	1	-320, 412.81	1	-320, 412.81
Year 1	211, 204.97	0.6135	129, 573.60	0.6098	128, 783.52
Year 2	221, 765.22	0.3764	83, 467.66	0.3718	82, 452.86
Year 3	232, 853.48	0.2309	53, 767.51	0.2267	52, 789.94

Year 4	244, 496.15	0.1417	34, 635.51	0.1382	33, 798.44
Year 5	256, 720.96	0.0869	22, 311.22	0.0843	21, 639.24
NPV			**3, 342.69**		**(948.80)**

Source: Computed from the Field Survey Data, 2023

IRR = 63+1[715.20/ (3, 342.69+948.80]

= 63 + 1 (0.7789)

= 63+ 0.7789

= 63.8%

The IRR of 63.8% indicates that the project is profitable because it is higher than the investment cost of capital which is 7.75%.

Table 11 represents the cash flow and present value calculations for a Sprinkler irrigation project in Butha Buthe. The project's internal rate of return (IRR) per hectare is 33%, also greater than the 7.75% investment cost of capital.

Table 11: Butha Buthe Sprinkler IRR/Hectare

Year	**Cash flow**	**Discount Rate (32%)**	**Present Value**	**Discount Rate (33%)**	**Present Value**
Year 0	-345, 504.94	1	-345, 504.94	1	-345, 504.94
Year 1	139, 183.79	0.7576	105, 442.27	0.7519	104, 649.47
Year 2	146, 142.98	0.5739	83, 874.53	0.5653	82, 618.00
Year 3	153, 450.13	0.4348	66, 718.38	0.4251	65, 224.74
Year 4	161, 122.63	0.3294	53, 071.43	0.3196	51, 493.21
Year 5	169, 178.77	0.2495	42, 215.92	0.2403	40, 652.54
NPV			**5, 817.58**		**(866.99)**

Source: Computed from the Field Survey Data, 2023

IRR = 32+1[5, 817.58/ (5, 817.58+866.99]

= 32 + 1 (0.87)

= 32+ 0.87

= 32.87%

The IRR for the Leribe sprinkler irrigation technology was 63.7%, compared to a significantly lower value of 32.87% for the Butha Buthe district. This correlates with NPV values for the drip irrigation methods. Hence, it is safe to conclude that Leribe micro-irrigation farming is more economical than the Butha Buthe district. The net present value index, and the internal rate of return index are popularly used for investment planning in different industries. According to this study, the two evaluation indicators are consistent.

3.6 Benefit Cost Ratio per Hectare

The benefit-cost ratio (BCR) is used in a cost-benefit analysis to summarise the overall relationship between the proposed project's relative costs and benefits (Hayes, 2022). It is calculated by dividing the total expected benefits of a project by the total expected costs. The calculations were done using the CBR formulae below:

$$BCR = \sum \left[\frac{B_t}{(1+r)^t}\right] / \sum \left[\frac{C_t}{(1+r)^t}\right] \text{...Equation 3}$$

Where Bt = Total Benefits in year t, Ct is Total Costs in year t, r = Discount rate $(1+r)^t$ = Discount factor and t = the number year.

The CBR values from the table show that both irrigation methods have positive cost-benefit ratios, indicating that the benefits outweigh the costs in both cases. However, drip irrigation generally has a higher CBR than sprinkler irrigation in both Leribe and Butha Buthe, as shown by the computations below.

Table 12: Leribe Drip Irrigation Discounted Benefits and Cost

Year	**Annual Benefits**	**Discount Rate (7.75%)**	**Present Value**	**Annual Costs**	**Discount Rate (7.75%)**	**Present Value**
Year 1	447, 336.86	0.9281	415, 173.34	205, 697.08	0.9281	190, 907.46
Year 2	469,703.70	0.8613	404, 555.80	215, 981.93	0.8613	186, 025.24

Year 3	493, 188.89	0.7994	394, 255.20	226, 781.03	0.7994	181, 288.76
Year 4	517, 848.33	0.7419	384, 191.68	238, 120.08	0.7419	176, 661.29
Year 5	543,740.75	0.6885	374, 365.51	250, 026.09	0.6885	172, 142.96
Total			**1, 972, 541.52**			**907, 025.71**

Source: Computed from the Field Survey Data, 2023

Therefore **CBR** = M 1,972, 541.52/ M 907, 025.71 = **2.2**

Table 13: Butha Buthe Drip Irrigation Discounted Benefits and Cost

Year	**Annual Benefits**	**Discount Rate (7.75%)**	**Present Value**	**Annual Costs**	**Discount Rate (7.75%)**	**Present Value**
Year 1	463, 209.88	0.9281	429, 905.09	228, 014.66	0.9281	211, 620.41
Year 2	486, 370.37	0.8613	418, 910.80	239, 415.39	0.8613	206, 208.48
Year 3	510, 688.89	0.7994	408, 244.70	251, 386.16	0.7994	200, 958.10
Year 4	536, 223.34	0.7419	397, 824.09	263, 955.47	0.7419	195, 820.01
Year 5	563, 034.50	0.6885	387, 649.26	277, 153.24	0.6885	190, 820.01
Total			**2, 042, 533.94**			**1, 005, 435.55**

Source: Computed from the Field Survey Data, 2023

The CBR ratio is calculated below based on the discounted benefits and cost cashflows shown on the table above.

CBR = M 2, 042, 533.94/ M1, 005, 435.55= **2.03**

Table 14: Leribe Sprinkler Irrigation Discounted Benefits and Cost

Year	**Annual Benefits**	**Discount Rate (7.75%)**	**Present Value**	**Annual Costs**	**Discount Rate (7.75%)**	**Present Value**
Year 1	397, 470.90	0.9281	368, 892.74	186, 265.93	0.9281	172, 873.41
Year 2	417, 344.45	0.8613	359, 458.77	195, 579.23	0.8613	168, 452.39
Year 3	438, 211.67	0.7994	350, 306.41	205, 358.19	0.7994	164, 163.34

Year 4	460, 122.25	0.7419	341, 364.70	215, 626.10	0.7419	159, 973.00
Year 5	483, 128.36	0.6885	332, 633.88	226, 407.40	0.6885	155, 881.50
Total			**1, 752, 656.50**			**821, 343.63**

Source: Computed from the Field Survey Data, 2023

The Leribe Sprinkler irrigation **CBR** = M 1,752,656.50/ M 821,343.63= **2.13**

Table 15: Butha Buthe Sprinkler Irrigation Discounted Benefits and Cost

Year	**Annual Benefits**	**Discount Rate (7.75%)**	**Present Value (Benefits)**	**Annual Costs**	**Discount Rate (7.75%)**	**Present Value (Costs)**
Year 1	312, 523.68	0.9281	290, 053.23	173, 339.89	0.9281	160, 876.75
Year 2	328, 149.86	0.8613	282, 635.48	182, 006.88	0.8613	156, 762.53
Year 3	344, 557.36	0.7994	275, 439.15	191, 107.23	0.7994	152, 771.12
Year 4	361, 785.23	0.7419	268, 408.46	200, 662.59	0.7419	148, 871.58
Year 5	379, 874.49	0.6885	261, 543.58	210, 695.72	0.6885	145, 064.00
Total			**1, 378, 079.90**			**764, 345.98**

Source: Computed from the Field Survey Data, 2023

Therefore, Butha Buthe Sprinkler **CBR** = M 1,378,079.90/ M 764,345.98= **1.8**

In Leribe, the CBR for drip irrigation is 2.2, meaning that for every monetary unit invested in drip irrigation, farmers can expect to receive a benefit of 2.2 monetary units. Similarly, in Butha Buthe, the CBR for drip irrigation is 2.03. On the other hand, the CBR for sprinkler irrigation is 2.13 in Leribe and 1.8 in Butha Buthe. In conclusion, based on the cost-benefit ratios presented in Table 12, drip irrigation generally appears more economically viable than sprinkler irrigation in both Leribe and Butha Buthe. A project with a BCR more significant than 1.0 is expected to deliver a positive net present value to a firm and its investors (Hayes, 2022).

3.7 Gains from Micro-Irrigation Technologies Usage

Small-scale vegetable farmers indicated that their usage of micro-irrigation projects resulted in increased food production and employment creation thereby improving livelihoods and revitalizing the economy of Lesotho. Productivity-enhancing irrigation result in the creation more self-sustaining and stable rural communities and in the long-run can help stem the tide of migration (Svendsen *et al*., 2009). Micro-irrigation technologies can help small-scale farmers to shift from subsistence production to higher value production for the market, increasing their income and greatly enhancing household and national food security.

Figure 2 below showed the results of vegetable production output for drip and sprinkler irrigation technologies in the study area.

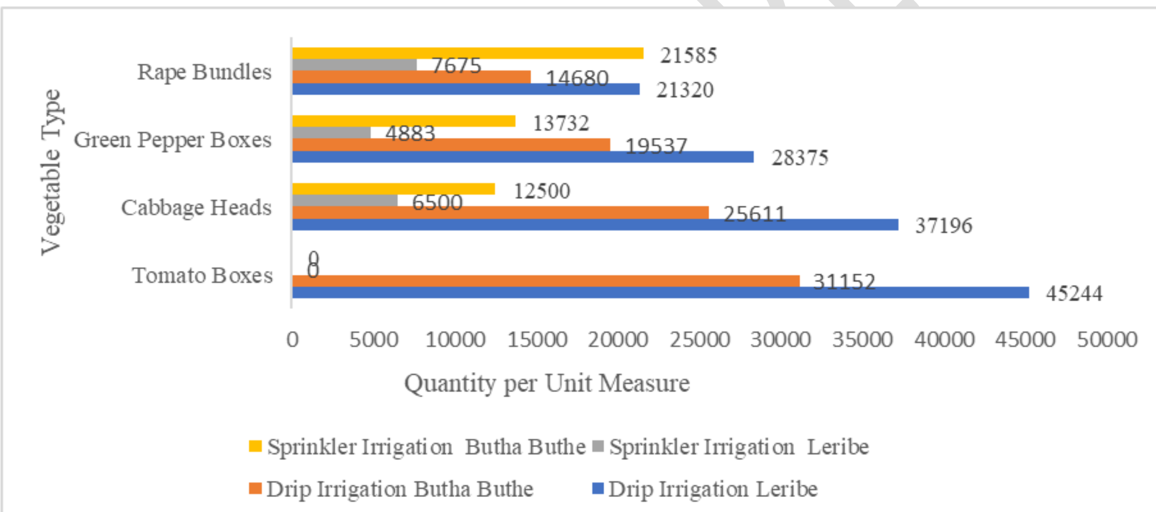

Figure 2: District Vegetables Production per Hectare

Source: Computed from the Field Survey Data, 2023

The respondents specialized in high valued vegetables such as cabbage, green pepper, tomatoes, and rape. Leribe drip micro-irrigation farmers produced more tomato (45244 boxes) than Butha Buthe drip micro-irrigation farmers (31152 boxes) and there were no farmers who produced tomato under sprinkler irrigation method. Rape was produced under drip and sprinkler irrigation in both districts with its highest production (21585 bundles) at Butha Buthe sprinkler irrigation and lowest production (7675 bundles) at Leribe sprinkler irrigation. Cabbage was also produced under all methods of irrigation with Leribe drip irrigation producing 37196 heads, followed by Butha Buthe drip irrigation with 25611 heads. Butha Buthe sprinkler irrigation farmers produced 12500 heads while Leribe sprinkler irrigating farmers were the lowest producers of cabbage with 6500 heads. 28375 boxes of green pepper were produced by Leribe drip irrigation farmers while 25611 boxes were produced by drip irrigation farmers from Butha Buthe. Figure 2 clearly shows that there was high production of cabbage, tomato and green pepper under drip irrigation for Leribe district. The shift from low-valued crops is influenced by the desire to maximize profitability of their farming ventures.

4. CONCLUSION

Different micro-irrigation technologies used by small-scale vegetable farmers in the Leribe and Butha Buthe districts are drip and sprinkler irrigation. The results from the study revealed that micro-irrigation farmers in Leribe (NPV for Drip: M426,961.93, NPV for Sprinkler: M610,900.05, IRR for Drip: 28.05%, IRR for Sprinkler: 63,8%, BCR for Drip: 2.2, BCR for Sprinkler: 2.13) are operating more sustainably and their ventures yield higher returns on investments than Butha Buthe farmers (NPV for Drip: M 41,391.75, NPV for Sprinkler: M268,228.98, IRR for Drip: 9.26%, IRR for Sprinkler: 32.87%, BCR for Drip: 2.03, BCR for Sprinkler:1.8.

Results of the study further showed that micro-irrigation usage resulted in increased productivity among the vegetable farmers.

The study recommended that financial costs should be mitigated to avoid their long-term impacts. There is however, a need for greater political and institutional input in irrigation farming; particularly enacting policy instruments that promote small-scale irrigation farming, including providing technical assistance, training, and accessibility to credit services that will facilitate the performance of micro-irrigation farming in Lesotho.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

REFERENCES

Boardman, A., Greenberg, D., Vining, A., Weimer, D., 2018. Cost- Benefit Analysis: Concepts and Practice. Cambridge University Press, USA.

Bwire, D., Watanabe, F., Suzuki, S,. and K. Suzuki (2024): "Improving Irrigation Water Use Efficiency and Maximizing Vegetable Yields with Drip Irrigation and Poly-Mulching: A Climate-Smart Approach". *Water* 16: 1-16

Bureau of Statistics. 2016. 2016 Lesotho Population and Housing Census. Analytical Report Vol. IIIB Socio-Economics Characteristics. Maseru, Lesotho.

Bureau of Statistics. 2018. Horticulture Statistics Report (2016/2017), Statistical Report No: 19 0f 2018

Cai, X., Chilonda, P., and Matete, M. 2016. Doubling Irrigation for Southern Africa- Do We Have Enough Water and Where is the Hope? International Water Management

Dejene, A., Midgley, S., Marake, M.V., and Ramasamy, S., 2011. Climate Change Adaptation in Agriculture: Experience and Lessons from Lesotho: Food and Agriculture Organization of the United Nations Rome, 2011

FAO. 2005. AQUASTAT Country Profile – Lesotho. Food and Agriculture Organization of the United Nations (FAO). Rome, Italy

Fernando, J. 2023. Discounted Cash Flow (DCF) Explained with Formula and Examples. Investopedia, New York City

Fernando, J. 2023. Internal Rate of Return (IRR) Rule: Definition and Example. Investopedia, New York City

Gibson, M. 2022. Sprinkler Systems vs. Drip Irrigation, Pros and Cons. California

Hayes, A. 2022. Benefit-Cost Ratio (BCR): Definition, Formula, and Example. Investopedia, New York City

Jayant, B., Dahiya, K., Rukhiyar, A., Raj, R. and Meena, K. 2022. A Review of th Drip Irrigation System. Delhi Technological University, India

Mphahama, L. 2011. Institutional Constraints to Horticulture Production and Marketing in Lesotho. MSc Thesis, University of Fort Hare. South Africa.

Mtetwa, S. 2018. Ministry of Agriculture and Food Security Lesotho: Agricultural Productivity Program of Southern Africa. Environmental and Social Management

Ntai, P. 2011. Critical factors determining successful irrigation farming in Lesotho. MSc Thesis, University of Pretoria. South Africa

Oduro-Ofori, E., Aboagye, P. and Acquay, E. 2015. Effects of Education on the Agricultural Productivity of Farmers in the Offinso Municipality. International Journal of Development Research Vol. 4, Issue, 9, pp. 1951-1960

Oladoyin, O., Adegoroye, A., Akinbola, A,. and E. Borokini (2023): “Unlocking the Economic Potentials of Leafy Vegetables: A Case Study of Farmers in Akoko South West Local Government Area of Ondo State”. *Asian Journal of Research in Agriculture and Forestry* 9(4): 327-336

Svendsen, M., Ewing, M., and Msangi, S. 2009. Measuring Irrigation Performance in Africa. International Food Policy Research Institute.

The Government of India. 2015. Prime Minister’s Agriculture Irrigation Programme: Introduction to Micro Irrigation Systems. India: Micro Irrigation Technician- Class XI

United Nations, 2011. Assessing the costs and benefits of adaptation options: An overview of Approaches. Geneva: European Climate Adaptation Platform

Velasco-Munoz, J., Azanar-Sanchez, J., Batles-delaFuente, A., and Fidelibus, M. 2019. Sustainable Irrigation in Agriculture: An Analysis of Global Research

World Bank, 2019. Lesotho Smallholder Agricultural Development Project-2. World Bank, Washington, DC.

Zizlavsky, O. 2014. Net Present Value Approach: Method for Economic Assessment of Innovation Projects. Elsevier Ltd, Czech Republic.