Evaluation of the impacts of clay brick production on water quality and socio-economic issues in Dididi Village, Limpopo Province, South Africa

by

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ABSTRACT

Clay brick production forms one of the preferred economic activities in rural areas. However, there is a competition for land and resources between brick production and other subsistence agricultural activities. This study was conducted to assess water quality and socio-economic issues related to small-scale clay brick production in Dididi village, Limpopo province South Africa. This study utilised positivism research philosophy and adopted a mixed-method research design in data collection. Questionnaires were adopted for this study together with field data collection measuring water parameters. Fifty (50) respondents provided input to the designed questionnaire, and 54 % of the respondents stressed on the negative impacts of clay brick production on the environment. Majority of respondents (84 %) reported that clay brick manufacturing provides business opportunities, hence a source of income. Clay brick production uses significant amounts of firewood in the kiln process leading to vegetation destruction, air pollution from the smoke, and potentially human respiratory challenges. Furthermore, liquid waste from the processes flows back in the river, increasing the total solids, suspended solids and this is an eyesore to the environment. From the collected water samples, the analysis showed no adverse effects in the river source for domestic water use according to standards stipulated by the Department of Water Affairs. For example, pH values were within the permissible regulatory range (between 6.0 and 9.0). However, continued monitoring of the activities in the area is recommended in policing environmental degradation since there was an indication of land degradation as a result of excessive use of sand.

DECLARATION

I Rabelani Mabogo (Student No. 64077683) declare that this dissertation **EVALUATION OF THE IMPACTS OF CLAY BRICK PRODUCTION ON WATER QUALITY AND SOCIO-ECONOMIC ISSUES IN DIDIDI VILLAGE, LIMPOPO PROVINCE, SOUTH AFRICA** is my own work and that all sources that I have used or quoted have been indicated and acknowledged by means of complete reference

Signature

31/01/2022
Date

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1. INTRODUCTION

1.1 Background

Population growth in developing countries, particularly in Africa (Ahmadalipour *et al.* 2019; Zimmer *et al.* 2020) has put tremendous pressure on available natural resources (Melina *et al.* 2016). The pressure is most prominent in the provision of housing, with most people seeking roofs over their heads (Turok and Scheba 2019). The issue of housing has brought about changes in people's lives in the urban and rural areas (Melina *et al.* 2016). Pressure on the provision of housing coupled with the increase in population has resulted in people shifting to brickmaking as a form of sustainable livelihood (Shackleton *et al.* 2007; Rajaratnam *et al.* 2014; Gallent 2019).

In this regard, due to the large expanse of land, people are gradually shifting towards the practice of small-scale brick production mostly on clay arable fertile soils (Grundy *et al.* 1993). The high activity in construction demanding cheaper material has led to an increase in demand for clay bricks. This has made clay brick production a lucrative business with quick returns (Mulwa 2019). The brick-making industry in less developed countries primarily uses traditional technologies whilst developed countries use modern machines that make bricks on a production line. The brick production requires clay soils that are also suitable for agriculture due to their high fertility and water retention properties (Goudie 2018). Hence the population is faced with a paradox of quick economic gains versus the one-season long crop production. Considering the socio-economic status of developing countries like South Africa, the choice is inclined towards quick income generation (Wanjule *et al.* 2015). Therefore, clay brick production is preferred and above all, the unreliability of the seasonal rainfall due to climate change (Goudie 2018) has pushed more population towards brick-making activities.

Rural Clay brick production is predominantly performed using Kilns which are thermally insulated chambers that produce temperatures sufficient to dry bricks (Inuwa 2019). Kilns have been in existence since 6 000 BC and they are different types of the oven that are used to harden objects made from clay, including ceramics and bricks (Hodges 1992). Brick kilns can be broadly classified into two main types i.e., traditional intermittent kilns and continuous kilns. Traditional intermittent kilns are small-scale in nature and rely on human labour (Hodges 1992). Kilns in this type include clamp, scove and downdraught. Intermittent kilns require low investments and produce poor quality bricks yet they use cheap, low-quality and pollutant fuels such as coal, biomass, wood, and plastic etc. (Rahman and Kazi 2019). An estimated 1,5 billion clay bricks are produced globally every year and most of the brick production is concentrated in less developed countries (Rajaratnam *et al.* 2014). Asia alone produces 87% of the world's bricks.

In Africa, and more specifically the Southern part of Africa (Southern African Development Community) clay brick production has been on an upward trend in recent years. South Africa produces 70% of the brick production in the region (Ncube *et al.* 2021). The Clay Brick Association (CBA) was developed in order to provides strategic direction for members through its substantial investment in research and educational initiatives. Although Clay Brick Association (CBA) continuously engages brick producers in community development programs with skill development and efficient manufacturing protocols. It is evident on the ground that there is no commitment to the rules and regulations as well as guidance provided by the association. More needs to be done in order to provide support to the informal clay brick producers in the rural areas who often lack the capacity, skills knowledge on the environmental impacts of the industry as well as financial resources to support their operations (Wanjule *et al.* 2015). Lack of accountability and limited law enforcement authorities on environmental management result in mismanagement of natural resources by the local communities. Although miners are supposed to be guided by the Code of Practice (COP) in South Africa, based on the implementation of brick production section 22 of the Mines Act Government (Gazette 2016, p23), which stipulates that miners should take reasonable care to protect their own health and safety, use protective clothing (Leon 1994). The Mines Act guidelines are used to ensure that clay brick manufacturing is conducted in a manner, which protects the environment, health and safety of miners. Hence, the Act is statutory guideline responsible for ensuring and enforcing compliance with the relevant Environmental Legislations. There is little evidence on the ground that shows that the miners (informal clay brick manufacturers) are following the rules and regulations. Moreover, the movement of trucks in and around the catchment area causes a health hazard to the nearby communities due to soil erosion and air pollution.

1.2 Environmental Impact Assessment and clay brick production

Environmental Impact Assessment (EIA) is a process of evaluating the environmental impacts of a proposed development, by considering possible positive and negative impacts on the environment thus informing decision-makers and the public (Morrison-Saunders and Retief 2012). EIA is designed to support the management of actual and potential environmental impacts related to project-specific developments (Roos *et al.* 2020). It is tailor made to predict environmental impacts earlier in project planning and design, to find ways that can assist in the reduction of negative impacts, resulting in more options to decision-makers (Morrison-Saunders and Retief 2012). EIA is being utilised around the globe to provide decision-makers and the affected public with critical information to plan for environmentally sustainable development (Aung et al 2020). Within South Africa, EIA is provided under the National Environmental Management Act 1998 (NEMA) which provides a guide to the environmental rights adopted in the Constitution (Morrison-Saunders and Retief 2012; Byambaa and de Vries 2020).

The process of EIA allows for the amalgamation of social, economic and environmental factors in the planning, implementation and evaluation of decisions in project execution (Malik *et al.* 2017). This is done to ensure that development caters for the present and future generations (Glasson and Therivel 2013). Generally, the EIA process starts with defining project activities, drafting the terms of reference, and then include public participation in the project implementation (Hasan *et al.* 2018). Any intended development in the environment is associated with the modification of the natural environment (Goudie 2018; Sarmah *et al.* 2020). Such modifications to the earth's environment include the destruction of vegetation, landscape, and manipulation of water resources (Goudie 2018). This means that most people venture into small-scale clay brick production, moving away from agricultural activities that have seen the agricultural outputs dwindle due to climate change (Wanjule *et al.* 2015; De Silva and Perera 2018).

Clay brick production industries have several adverse impacts on the environment and the local community, which include water pollution, deforestation, desertification, air pollution and soil erosion (De Silva and Perera 2018). It is, therefore, necessary to have efficient monitoring efforts of the clay brick production at small scales. Although the activities of clay brick production are at local levels, the activities necessitate an evaluation of the impacts using EIA (Malik *et al.* 2017).

There has been debate about the measurement of EIA effectiveness in environmental management (Sadar 2002). However, despite the international recognition and adaptation of EIA and its procedural integration into project planning and decision-making systems, questions have increasingly been raised about whether EIA is achieving its purposes (Annandale *et al.*, 2021). Its influence over the final decision appears to have been less than its originators anticipated (Shakil and Ananya 2015). Numerous studies have been undertaken to assess to what extent EIA is achieving its purpose. Most of EIA focused on procedural requirements (Hansen and Wood 2016). However, increasing attention is being placed upon evaluating EIA according to more substantive criteria to judge whether EIA is resulting in the kind of outcomes that are typically sought. This has generally been referred in terms of EIA effectiveness.

1.3 Research problem

According to the Manufacture of Clay And Concrete Bricks report, since 2010 there has been a boom in the manufacturing of clay bricks due to increasing demand for residential property. While industry output has remained relatively constant since 2014 at approximately 3.6 billion clay bricks are produced per year. However, there are no figures from the informal brick manufacturers as they are not registered members of the association. Hence this study focused on this obscure sector to add into the registered formal clay brick manufacturer data.

Brick production is the second most prominent sources of income in rural areas after subsistence farming (Omotoso *et al.* 2020). This has seen the appearance of Kilns around the Luvhuvhu catchment (Amposah-dacosta and Mathada 2017). The catchment serves as a suitable location because of the availability of raw materials (water, clay and wood) for brick production. Matsiketa (2018) conducted a study on development of product quality management guidelines for informal small-scale brick manufacturing enterprises in Divhidi. Their study specifically focused on the development of product quality management guidelines. Notably, the study area is dominated by Scove kilns (Senzanje *et al.* 2008) which are mostly built by landowners or informal clay brick manufacturers leading to the existence of isolated pits due to the excavation of the soil for clay brick production that is hazardous to both human beings and livestock. There is need to explore on the socio-economic and environmental impacts associated with clay brick production.

Jerin *et al.* (2016) assessed the impacts of brick fields on the environment and social economy at Bagatipara, in Bangladesh. The findings of this study were based on randomly selected respondents' perceptions of changes to the environment. Nidzam *et al.* (2016) assessed the strength and environmental evaluation of eco-friendly brick production. Survey results illustrated that the emission of dust particles, harmful gases, and hot air cause several health hazards such as asthma, eye or skin irritation. These studies were conducted in a different environment (Asia) and were based on respondents' perceptions and did not incorporate measurements of water quality. There is a need to evaluate physicochemical parameters and socio-economic impacts of clay brick production in the rural communities in Limpopo Province, South Africa. Overall, it is not known, to what extent does the brick manufacturing industry in the Luvuvhu catchment affects the socio-economic livelihoods as well as the available water resources, thus necessitate an investigation of such issues.

1.4 The Research Question

The main research question is whether the brick making activities in Dididi village are having an impact on the environment and socio-economic activities in the area?

In answering the above question, the following sub-questions formed part of the study.

i. Does the brick-making industry in Dididi village change water pH, conductivity, and other parameters to non-compliance levels as stipulated by Department of Water and Sanitation?

ii. Does the brick-making industry have an impact on social factors (school dropouts, low income, father absentee's, crime and violence)?

iii. Does the brick-making industry have an impact on the economic situation of the people in the Dididi village?

1.5 Aim and objectives

The aim of the study was to evaluate the effects of clay brick production in Dididi Village on water quality and socio-economic status of the residents of Dididi village, Limpopo.

The aim was addressed through fulfilling the following specific objectives, which were to:

I. determine water quality parameters (pH, dissolved oxygen, chloride, total dissolved solid, total alkalinity, calcium, magnesium, total hardness, nitrate and electrical conductivity) in the Luvuvhu catchment;

II. Evaluate the social impacts of the clay brick production in the Dididi village; and

III. Evaluate the economic impacts of the clay brick production on the Dididi village.

1.6 Structure and organisation of the Thesis

This Thesis is structured into five chapters.

Chapter one presented the current perspective and background information about the research topic. The chapter provided the study focus, the problem statement as well as its aims and objectives, coupled with highlights on the importance of the study and the parameters guiding the investigation mainly in terms of the main research question.

Chapter two focussed on literature review which appraised the key issues related to the study. The choice of scholarly articles, journals and other resources for the literature review were guided by the research sub-questions and the theoretical context of clay brick production. The Literature review provided the summary of works that are in line with the study.

Chapter three presented the methods of the study by focusing on processes taken within a mixed method design study approach. The chapter zoomed in on the nature of data acquired from both the secondary and primary data sources which included interviews, and site visits. The chapter also explains the different tools used to acquire the data as well as the approach used for data analysis and derivation of findings.

Chapter four presented the research findings.

Chapter five provided the discussion of the findings of the study which have been provided in the results section. The chapter answers the main research question by integrating the findings of the study as derived through the substantive chapters. In addition, chapter five makes recommendations from the study.

2. LITERATURE REVIEW

2.1 Introduction

Over the years livelihood options in the rural areas across the developing countries have become heavily dependent on subsistence farming (Khapayi and Celliers 2016). The Food and Agriculture Organization (FAO) estimates that agriculture provides employment to 1.3 billion people globally, and approximately 97% of the people are found in developing countries (Rapsomanikis 2015). Rural households have been shifting to other rural labour market activities such as rural nonfarm economic activities; and others migrating to towns, cities, or other countries (Lanjouw and Lanjouw 2001). Most notably, the continued climate changes and reduced soil fertility have affected agricultural production leading people to opt for other survival options (Voss 2021).

With agricultural productivity growth slowing down and a growing population in developing countries, smallholder agriculture faces challenges to meet growing demand and generating adequate jobs at reasonable wages to contribute to economic growth. Thus to some extent, it a slump in agricultural productivity has been attributed to a major shift of people's livelihood options related to economic activities such as small-scale manufacturing industries (Li *et al.* 2019). Rural households design livelihood strategies to suit their asset endowments and account for the challenges due to market failures, state failures, social norms. One typical example of the livelihood options is the clay brick production that has been practiced since ancient times (Sparrevik *et al.* 2015).

Traditional clay brick is a product of a brick dough, which consists of clayey soil and water and it is formed primitively, naturally dried, and fired in the kilns in the workshop (Dalkılıç and Nabikoğlu 2017). Traditional clay brick is the oldest and most used building material, that is manufactured near a reliable water source and where suitable soil is found (Ward-Perkins 1981). Small-scale clay brick production in the rural areas is associated with on-the-job training, whereby people learn from the already skilled workforce, thus it is the immediate popular trade that supports livelihoods in the rural areas (Mase *et al.* 2017).

2.2 Essential conditions and production of fired clay bricks

In general, fired clay bricks are moulded with a composition of up to 60 % sand/silica, with 20 to 30 % alumina and up to 5 % lime. Clay bricks are handmade brick from baked clay in an oven at about 1200°C (Khalaf and DeVenny 2005). A production unit for clay brick production needs good quality clay to for strong bricks (Khalaf and DeVenny 2005). Notably, certain types of clay are not good for making fired bricks, for instance, the clay used by a potter to make bowls cannot be good for brick making because it has a high shrinkage rate that causes the bricks to crack during drying (Zhang 2013). In order to produce clay bricks there must be sufficient water such in close proximity to a lake, or stream (Boyd 2012). Water is essential for clay brick production because it is used for the tempering process allowing bricks to stand undisturbed for a few days before mixing (Zhang 2013). However, it is not ideal that brickmaking competes for the same water source used for human consumption (Mulwafu 2014). Additionally, sand is essential for brick making process since it is used as a releasing agent during the moulding of bricks. It prevents the wet clay from sticking to the sides of the mould. Sand is also utilised as a stabiliser and mixed with very clayey soils to prevent the bricks from cracking when drying (Rix 1998).

To fire the bricks well, there is need for enough fuel and this can be derived from firewood or coal, henceforth firing brick kilns use large quantities of wood (Emrich1985). Clay bricks must have enough strength to carry the weight of a building, and this is mostly related to materials used in the process (Kumar 2002). After mixing, the clay can be used immediately for moulding into bricks or returned to the tempering tanks where it is kept, until the next process (Figure 2.1). Moulding is the process where the prepared clay is placed in a mould which forms it into the shape of a brick. There are two methods of moulding bricks using manual labour and these include the slop moulding method and the sand moulding method (Singh and Munjal 2017). Sand moulding is a drier method of shaping bricks that assist in preventing problems found in traditional slop moulding. Sand moulded bricks dry more quickly with less cracking because less water is used during the clay preparation stage. This is advantageous for brick sites which suffer from a shortage of water.

After the moulding process (Figure 2.1) is finished, the next stage is firing the kiln with a small gentle fire of low heat in the centre of each tunnel (John 2018). The purpose of this process or stage is to drive off all the water or moisture in the bricks. During this stage a white vapour comes out or steam rising from the top of the kiln (this is the water being released from the bricks) (Singh and Munjal 2017). The small fires are maintained until the white vapour or steam is no longer coming from the top of the kiln. This stage of firing lasts for two days or more, depending on the size of the kiln and the moisture content of the bricks. At the end of this phase, the temperature of the kiln should reach approximately 150°C. It is essential to note that a wood fire needs air to burn well but too much air can cool the fire and reduce the temperature of the bricks and increase the consumption of firewood

After preheating the main firing begins and will take a total of four to six days to complete. The objective of this stage is to bring all parts of the kiln up to the correct firing temperature of approximately 950 °C (Armstrong 2011). On one side of the firing kiln, all tunnel openings are blocked up completely with bricks which is plastered together with mud (Figure 2.1). On to the other side of the kiln, firewood is fed into the tunnels to build up a large hot fire. This main firing process will last about two to three days or until the bricks in the tunnels begin to glow red (Walters 1982). When the bricks in the tunnels are glowing red, the tunnels which were open during the first two or three days of the main firing are blocked up with brick and mud mortar and the ones which were initially blocked are broken open (Armstrong 2011). Firewood will continue to be fed in from the open side until the bricks in the tunnels glowing yellow-orange colour. The second half of the main firing stage will last for at least two or three days depending on how well the fires are fed and the size of the kiln. It is important that the field kiln is allowed to cool down as slowly as possible. This means that the kiln should not be opened for at least two weeks and preferably four weeks after the kiln has been completely sealed (Armstrong 2011). If the kiln is opened too soon, some of the bricks may be cracked by the cool air rushing into the kiln. The bricks will obtain a higher strength if the kiln was fired and sealed well and allowed to cool slowly and naturally (Walters 1982).

Figure 2.1 Rural clay brick manufacturing process (a) Brick preparation for cooking; (b) Oven; (c) yellow bricks after fist cooking and (d) red brick after second cooking.

2.3 Impacts of traditional brick kiln technology to the environment

The role of the traditional brick kiln technologies in producing pollutants and its impact on the environment has received increased attention over the years (Sanjel *et al.* 2016). The impact of traditional brick kilns is triggered by the nature of the emissions from the chimneys during the firing process and the high usage of fertile topsoil to make solid bricks. The firing process and the structural design of the kilns do not allow enough ventilation, resulting in inefficient fuel-air mixing and incomplete combustion of fuel (Sanjel *et al.* 2016).

Production of fired bricks also causes emissions for greenhouse gases and other pollutants such as contaminated smoke containing carbon monoxide (CO). On average CO emission in India is as a result of combustion of coal during firing of the kiln which is as estimated at 80.7 kg CO per thousand bricks (Nath *et al.* 2018). Exposure to air pollution is linked to a wide spectrum of health effects that can be acute or chronic in nature and will vary with concentration of pollutants. Particulate air pollution exposure can lead to lung cancer and other cardiopulmonary mortality. Health impacts of emissions from PM for AP has been analysed for cardiopulmonary disease, lung cancer and lower respiratory tract infection for children under the age of five year.

The reliance on large quantities of good quality soil also causes environmental degradation. Clay is obtained from excavating fertile alluvial soil from river beds, and agricultural land (Nath *et al.* 2018). As a result, a non-renewable (soil) resource is becoming exhausted and problems such as soil erosion, depletion of soil quality and flooding are increasingly emerging (Skinder *et al.* 2014). Soils found around abandoned clay brick production sites are inherently low in fertility and cannot support higher crop yields even under fertilizer treatment. Increase in concentration of heavy metals, such as nitrate and sulphate near brick kilns results in reduced soil quality. Soil contamination around brick making facilities may also lead to distortion of plant biomass, alteration of plant structure as well as change in species diversity.

International Labour Organization (ILO, 2013) report on the health of children and youth who have been working in brick kilns in Asian countries found that respiratory diseases are one of the health conditions suffered by children. Skinder *et al.* (2014) state that there is a connection between brick kiln air pollution and premature deaths, including research by the World Bank in Bangladesh which found that brick kilns are responsible for premature deaths every year in the country

Land degradation can further be linked to brick manufacturing processes. Khan and Vyas (2008) study in India on the banks of Kshipra River, India and found that digging for clay leads to slashing and burning of vegetation at the brick kiln sites, and subsequently results in soil depletion and crop failures. The effect is long-lasting with brick kiln sites becoming barren pieces of land once the operations. In addition, black carbon can adversely affect agricultural production by reducing the amount of sunlight that reaches the Earth's surface. Through its emission of CO_2 and tropospheric ozone (O_3) the traditional brick kilns also impact the weather pattern in Asia, affecting tropical rainfalls and regional circulation patterns such as the Asian monsoon, which may increase the destructiveness of tropical cyclones.

Khan *et al.* (2019) conducted a study in Pakistan on the impact of brick production using traditional kilns on the environment and human health. Their study reported that low-quality coal is used as a fuel that produces harmful pollutants. Because there are no checks on the brick kilns, therefore the use of rubber in the kilns produces sulphur dioxide (SO_2), carbon dioxide (CO_2), nitrous oxide (NOx) and other harmful substances. The pollutants formed from brick kilns affect plants, people, water and soil. When the harmful substances/chemicals flow into the river or sea, may harm aquatic life. Moreover, these chemicals are absorbed by the soil, changing the soil pH. Khan *et al.* (2019) study also showed that diseases such as asthma, chronic obstructive pulmonary symptoms, and silicosis are as a result of harmful emissions from the brick kilns. Overall, the responsible authorities issued orders to close the brick kilns four days a week in winter. Owners of brick kilns were encouraged to use alternative methods and those workers who do not afford the use of entirely new technologies were provided with funds to modify their brick kilns.

David *et al.* (2020) evaluated the environmental effects of heavy metals on biochemical profile and oxidative stress among children at brick kiln sites in Rawat, Pakistan. It was reported that workers and children living close to brick kiln sites were at increased risk of exposure to environmental pollutants. In Rawat, the brick kilns and road transport smoke pose a huge burden of air pollution on human health and the atmosphere. The behavioural patterns of children such as playing in mud barefoot increases their direct contact with dust and raise inhalation problems which weakening their immune system.

In most areas around Pakistan people uses zig-zag technology-led brick kilns to fight air pollution (John, 2018). Zigzag Firing kiln is a continuous, cross draught, moving fire kiln in which the air flows in a zigzag path due to the draught provided by a chimney. Traditional fixed chimney bulls trench kiln unlike the zig-zag technology-driven brick kiln place bricks in a straight pattern. The zig-zag pattern allows for efficient manoeuvring of the air for heating purposes. Use of Zig-Zag technology in construction and operations of kilns can minimise the effects of burning coal on environment and reduce the fuel consumption up to 30 per cent Additionally, the black soot that comes out of the traditional brick kiln is due to the inefficient burning of fuel, whereas the zig-zag setting of bricks and continuous loading of small quantities of coal improves fuel efficiency (Vlades *et al.* 2020). As a result, the emitted smoke from the kilns employing zig-zag technology is white coloured and with significantly low air pollution levels. The Induced-Draught zig-zag kiln type also has a fan, which allows controlling of air, thereby making the coal burning process even more efficient (Valdes *et al.* 2020). Matsiketa (2018) conducted a study on development of product quality management guidelines for informal small-scale brick manufacturing enterprises in Dididi. In their study, chemical analysis was carried out to determine the chemical composition of the soil and they reported elevated silica contents with minor amounts of alumina and iron oxide.

2.4 Clay brick production and employment creation

The livelihoods of the once agriculture-based communities have been made increasingly vulnerable by successive droughts, desertification and deforestation which is largely due to climate change (Dube *et al.* 2016). Diversification strategies have included men's casual labour shift toward clay brick manufacturing. At an international scale, it is estimated that India has more than 100 000 brick kilns producing about 250 billion bricks annually, and employing 15 million workers (Kumbhar *et al.* 2014). The clay brick industry continues to grow as the demand for bricks is increasing in the villages due to the fast economic growth, and urbanization (Wanjule *et al.*, 2015). Most of the brick production in rural areas of Indonesia, is carried out by cottage and village industries accounting respectively for 24% and 43% of total production. The remaining 33% is produced by relatively large-scale brick plants. These people are entrepreneurs who should be assisted to formalise their businesses and make them sustainable.

In Africa, for instance, in Zimbabwe informal clay brick production takes 13% of the market share of countries brick production industry (Clay Brick Association of Southern Africa 2017). Furthermore, in Botswana, the informal sector is relatively small in comparison to the large volume of clay bricks manufactured. Their total production per annum is less than 5% of the market, whilst in Lesotho, it is 25% and Malawi 50%. In most cases local brick production is largely in the hands of middle-class businessmen, who reap the main profits and pay little to the workers (Östberg *et al.* 2018).

Most small-scale brick production industries in South Africa provide the much-needed income used in households (Hilson 2006). Small clay brick production in South Africa and neighbouring countries produces thousands of fired bricks per month and create jobs for the local people (Nel *et al.* 2014). In some townships around South Africa many houses are built out of earth bricks (clay brick production). Thus, the tradition of making and using earth bricks is thus well known and contributing to employment creation. The raw earth bricks can be produced and sold at a very low price (35 - 55 cents per brick) (Cermalab 2014).

Through the construction of dwellings and other buildings, skills development can take place to create quality jobs – jobs that themselves generate employment opportunities for those who have not been exposed to vocational training (Nyambo 2017). The need for public buildings and other forms of infrastructure in areas of poverty and high unemployment can provide a guaranteed flow of work that can be linked to ongoing skills development and entrepreneur support initiatives (Nyambo 2017). In decentralized areas suffering from high levels of unemployment, an important objective is to retain as much of a building project's cost as is feasible within the target community. This requires design and specification that maximizes the use of local materials, locally manufactured bricks, transport, local energy sources, as well as local labour force (Mitchley 2003).

2.5 Support to rural clay brick manufacturers

Currently, majority of informal clay brick manufacturers in the Limpopo province constitute of foreign nationals, hence they are reluctant to engage with responsible authorities (Clay Brick Association 2018). Furthermore, issues such as understanding of land ownership according to South African legislation especially among traditional leaders hinder progress in formalising the small-scale clay brick manufactures. In other instances, traditional leaders are giving permission for clay mining on the land that they do not have ownership over. Governments may provide the necessary funds and technical assistance to improve existing clay brick production using tradition kilns and work with a few selected manufacturers to develop and demonstrate new technology (Rissman *et al.* 2020). Interestingly, many of the individuals involved will have ideas on how to improve not only the performance of the kiln but also the operation. There is a need to implement demonstration programmes. These programmes should not only focus on the introduction of more fuel-efficient and cleaner-burning kilns and furnaces but also explore the feasibility of introducing new fired and unfired clay products (Wanjule *et al.*, 2015).

Although financing schemes for the small-scale industries exist in many countries, brick manufacturers may not always be able to avail themselves of this financing for various reasons including bureaucratic red tape, the fact that brick industries are not considered as an industry due to their lack of registration (Rissman *et al.* 2020). Governments may assist by recognizing small entrepreneurs, providing inexpensive financing or making special-purpose funds available. In order to rejuvenate the rural building materials industry training is essential for contractors, tradesmen, architects, craftsmen and employees of building materials enterprises (Zhang *et al.* 2020). This training would be most effective if it was channelled through industry groups such as a national brick producers association. It will also be important to ensure that there are regular seminars for all professionals and industry owners to discuss issues such as the use of alternative building products, standards etc. (Ashande *et al.* 2019).

2.6 Clay Brick Association, South Africa

The Clay Brick Association of South Africa (CBA) was formed in 1963 as an association of South African brick manufactures, to provides information about the operations of clay manufacturing industry and financial assistance to its members (Clay Brick Association 2018). Furthermore, the CBA publishes educational books and technical guides about building and maintaining (Clay Brick Association 2018). To assist clay brick producers to maintain standards and understand building regulations, the CBA presents free workshops at conferences and professional association meetings. The CBA further maintains regular contact with the Department of Mines, Minerals and Energy, and the Department of Human Settlements, to ensure government regulations are practical, sustainable and adhered to (Clay Brick Association, 2018). The association forges progressive ethics with the important reviews, necessary to promote stringent quality and operational standards in the industry, following the stipulated guidelines of SABS 227 (Clay Brick Association 2018). The CBA teaches its members sustainable manufacturing practices and provides technology tools and incentives to assess production processes to reduce local greenhouse gas emissions (Clay Brick Association 2018).

The CBA Association also provides strategic direction for its members through its investment in research and educational initiatives. Member companies are continually improving the quality and sustainability of clay masonry products with innovative production methods. Membership is voluntary, with the prerequisite that members uphold the integrity of the Clay Brick mark and supply only top-grade clay masonry products (Clay Brick Association 2018). Clay Brick manufacturers are focusing on the implementation of ISO and other international quality measurement and management systems that encompass all aspects of the operation.

Through technology, the CBA has broadened its education initiatives to meet the needs of homeowners, and construction professionals. The Association is renowned for its first-rate technical information, making it easy to efficiently design, detail and build with clay bricks. The CBA publishes both online and printed educational books and technical guides about building and maintaining bricks and pavers. The organisation advises regulatory bodies on energy efficiency during construction and operation, Carbon Tax and SABS standards in brickwork. The CBA fosters a progressive ethic with the vital checks and balances in place to promote stringent quality and operational standards in the industry, following the guidelines of

SABS. Through its complex commitment to the quality and professionalism of the industry, the CBA supports proven building technologies. The CBA noted that the use of poor quality, cheaper materials, or unproven technologies in low-cost housing has resulted in sub-standard structures. The CBA provides strategic direction for members through its substantial investment in research and educational initiatives.

Clay Brick manufacturers focus on the implementation of ISO and another international quality measurement as well as management systems that encompass all aspects of the operation. The CBA has invested in research studies to prove the performance of Clay Brick products as the best long-term affordable housing solution. Creating and supporting local industries that add value to natural resources is a critical strategy for South Africa. Clay brick provides stimulus for local job creation and skills development while reducing our dependence on imported construction materials. It should be noted that there is a national drive in partnership with the Swiss Agency for Development and Cooperation (SDC). The entity is designed to educate CBA members on sustainable manufacturing, firing practices and provides technology tools and incentives to assess and update production processes. The programme's goal is to reduce local greenhouse gas emissions.

2.7 Socio-economic impacts of brick making

The brick-making industry in South Asia relies on the manual labour of millions of workers. Up to 68% of the workers in South Asia are estimated to be working in bonded and forced labour conditions (Ashande *et al.* 2019). Medium-sized kiln employs 50 to 100 workers on average, with 50 workers producing around 400,000 bricks in one month. In order to meet the demand of workers, every year individuals, as well as unaccompanied children undertake in-country or regional migration to work in the kilns (Rissman *et al.* 2020). Cermalab (2014) study in Asia noted that although rarely identified as a separate group facing specific issues, women and young women are very often part of the workforce in the brick manufacturing industry. They are directly acknowledged as labour except when they are liable to pay for their outstanding debts. Women are exposed to physically demanding tasks including even during pregnancy, leading to significant risks to their babies and their own health. Furthermore, they are also extremely vulnerable to violence, abuse and sexual harassment. Research across Asia, noted that labourers found that brick kiln owners often took sexual favours from the wives or daughters of bonded labourers as payment for advances of food and clothing (Kumbhar *et al.* 2014).

Clay brick manufacturing in rural locations and tend to be far from healthcare facilities. When healthcare services are available, they do not cater for migratory workers because the host location cannot deal with the seasonal influx of population (Cermalab 2014). As a result, when suffering from an illness or injuries, workers self-medicate without proper use of proper medication. In some instances, there is the use of unqualified doctors who put them at risk of injury and even death. In response to this, the Organisation of Economic Cooperation and Development (OECD) have introduced guidelines for multinationals stating that companies buying bricks from small-scale clay brick manufacturers violating human rights should have direct responsibility for human rights abuses (Weyant *et al.* 2014).

Socio-economic sustainability concerns the parameters that affect people's current and future opportunities to fulfil their potential as well as attain their basic needs such as livelihoods, social and environmental justice, and human rights (Glickman and Servon 1998). The clay brick sector can go further in this regard by empowering employees, collaborating with the local communities and clay brick sustainability research and reporting (Glickman and Servon

1998). Continuous employee development is a good way of ensuring that workers replenish and acquire new skills that can benefit them within and out of the workplace to improve their standards of living (Huber *et al.* 2003). Some of the areas of development could be in financial literacy and public health and technical skills (Wood, 2003). Wider technical and practical skills development for communities and the public can be attained through apprenticeships for students, workshops and partnerships with colleges/universities. This could be in skills that may not only be applicable in the brick-making sector but other relevant areas for the development of the communities. It is also through such skills development workshops that the informal brick producers can be approached and information is shared on the best practices for business and brick making and how these can be incorporated at their different scales (Schmidt 2013).

Sourcing products and services within their local communities and growing community-based organizations to meet their demands aids in the growth and development of local suppliers (Zapatta *et al.* 2011). These can grow to meet the company's demand as well as that of other companies that require similar products or services. Some of the products and services that can be sourced locally include the following:

- ✓ Recycling and production of plastics for transportation and covering of bricks;
- ✓ Recycling and production of pallets for the transportation of bricks; and
- ✓ Mechanical and electrical maintenance services.

South Africa's socio-economic profile remains highly unequal two decades after the first democratic elections. The CBA's Social Life Cycle Assessment for Clay Bricks finds that members remain committed to South Africa's development in a way that balances the needs of society, the environment, and increased levels of economic production. The health and safety of employees are of high priority for the CBA Members, who are committed to fair and ethical labour practices. Socio-economic sustainability within the clay brick sector relates to a range of issues. These include aspects within the workplace as well as considering the broader context of the sector's practices, its impacts, and contribution to economic development. The Social Life Cycle Assessment for Clay Bricks identified the following impact areas concerning the socio-economic context of the clay brick sector:

- ✓ Human rights;
- ✓ Working conditions;
- ✓ Health and safety;
- ✓ Cultural heritage; and
- ✓ Governance

2.8 Regulation of small-scale clay brick production

Brick making is a variant of small-scale mining thus, the same legislation as large-scale mining for compliance should be put in place (Mutemeri and Peterson 2002). However, recent years have witnessed several changes in the governance of mining in South Africa that rendered in many ways to distance the industry from its disreputable past towards a more progressive and sustainable future (Ledwaba and Mutemeri 2018). One of the most important changes was the passing of the amended Mineral Development and Petroleum Act, (2008) which fundamentally shifted the control of mineral rights to the state. Such an undertaking was considered in enhancing more equitable access to the country's mineral resources.

Furthermore, the act ensured that mining companies contribute, through newly required social and labour plans, to skills development amongst employees as well as to local economic development and social uplifting in the areas in which they operate (Dreschler 2001). In addition, it is within a more progressive context and in recognition of the dramatic decline of formal large-scale mining in South Africa that the Department of Minerals Energy has turned its attention to smaller-scale operations. The policy commits the government to facilitate the development of small-scale mining into a sustainable, profitable, healthy, safe, and environmentally friendly sector (Dreschler 2001).

The policy outlines the development of institutional support to facilitate and support needs, driven research, funding, training, delivery of information and guidance and advice on mineral development and regulations (Ledwaba and Mutemeri 2018). The policy states that: All spheres of government and development agencies will work towards coordinating their activities in respect of the promotion of small-scale mining activities (Nsengimana *et al.* 2017). Municipalities will be encouraged to support the development and emergence of small-scale mining through appropriate local economic development strategies (Ledwaba 2017).

The informal economy is acknowledged by all levels of government as representing a real and significant component of the South African economy, with their estimated input being between 7 % and 12 % of national GDP. Regardless of this, there appear to be no coherent policies specifically tailored to support the informal economy at the government level (Cermalab, 2014). At the same time, a National Steering Committee (NSC) of Service Providers to the small-scale mining sector and regional small-scale mining Committees were formed to streamline institutional support specifically for the lower end of the sub-sector and to correct the practices of artisanal mining especially unacceptable safety standards and environmentally unfriendly methods (Mutemeri and Petersen 2002; Hossain *et al.* 2019). Department of Economic Development, Environment, Conservation and Tourism encourage women behind a brick manufacturing cooperative to grow their business from strength to strength. For instance, Tfutfukani is a brick making cooperative which is strategically placed at the heartland of developing areas and nearby Nelspruit which is the economic hub of the region.

2.9 EIA and Sustainable development Goals

Hacking (2019) postulated that it is not yet possible to form impact assessment explicitly in support of the SDGs. Environmental impact assessment procedures are evolving. While at the beginning SDGs primarily focused on identifying effects and impacts on the physical and natural components of the environment. The procedures assess impacts on the social, cultural and anthropological components, although there is still a lack of methodologies for integrating the studies of aspects of the human environment (Mutemeri and Petersen 2002). Furthermore, while the results of the impact assessment studies, the environmental impact statements, were primarily used as a litigative tool to prevent and stop a proposed project, they are now used more to enhance the planning process. Alternatives for siting, raw materials used, manufacturing processes employed, products produced, and waste treatment methods to be incorporated, are some of the options that could be generated and assessed so that the combination that will use natural resources more efficiently and will have the least impacts on the human environment can be chosen for the plans and designs (Hacking 2019). EIA has an important role to play since its widespread adoption can provide a platform for the development of increasingly sustainability-focussed techniques or processes. Thus, there is a need to incorporate EIA in projects that affect the environment.

Impact assessment tools have been applied internationally to ensure that proposed actions are economically viable, socially equitable, and environmentally sustainable ((Wood 2003; Dutta and Bandyopadhyay 2010). The well-developed legislative and policy framework in the region, combined with the great challenges for sustainable development in southern Africa creates the opportunity for EIA to play a leading role. For EIA to fulfil its real potential, South Africa requires capacity building for administrators, earmarked for monitoring of compliance with EIA recommendations; sharing of 'best practice' (González, 2021). There is also a need to remove the notion that EIA is an obstructive process that keeps people in poverty rather than one that ensures future generations (Kafwimbi, 2015).

Impact assessment tools have been applied internationally to ensure that proposed actions are economically viable, socially equitable and environmentally sustainable. The relatively well-developed legislative and policy framework combined with the great challenges for sustainable development in southern Africa, create the opportunity for EIA to play a leading role. South Africa needs to invest in the following aspects (i) capacity-building for administrators, (ii) practitioners and the public; (iii) monitoring of compliance with EIA recommendations; (iv) linking EIA with the full project life cycle; (v) harmonisation of legislation and strengthening the links between EIA and other high-level decision-making processes. There is also a need to dissipate the notion that EIA is an obstructive process that keeps people in poverty rather than one that ensures future generations will enjoy resource security and good quality of life (Alder and Wilkinson, 2016). Development that caters the needs of the present generation without pre-empting the ability of future generations to meet theirs, is beginning to be recognised as a policy that should be pursued for ecological, social, ethical as well as political expediency. Environmental impact assessment procedures provide the means to identify the technical constraints to plan and implement sustainable development projects.

Kørnøv *et al.* (2020) reported that Environmental Assessments have been envisaged as critical to achieve Sustainable Development Goals. Furthermore, it is assumed that the SDGs will likely become a central component of future environmental (Weaver *et al.* 2002; Alder and Wilkinson, 2016). SDG-based integration with environmental assessment characterises an should constitute a decision-support tool that is far more proactive than the legislative environmental assessment. The integration should provide decision makers with an overview of how SDGs can be achieved through different decision alternatives with different scores for goal achievement. In this integration, the SDGs need to be combined with the strongholds of environmental assessment in terms of procedures that allow for involving authorities and the public in the process, an approach for focusing the assessment (Kørnøv *et al.* 2020).

2.10 Case Studies on clay brick production impacts on the environment

Ashande *et al.* (2019) conducted a study analysing socio-economic and environmental impacts of the manufacturing of clay bricks in Gbado-Lite city, Democratic Republic of the Congo. In this study the authors' interviewed 30 clay brick manufacturers on how they conduct their business and assessing the socio-economic impacts of the business in the local community. From the survey it was noted that the respondents knew clay brick manufacturing activities results in loss of several plant species. However, due to level of education of and socio-economic pressure on the respondents, they mentioned that they only concentrate on getting income rather than the immediate environment. This study is closely linked to the current study which associates clay brick manufacturing activities with socio-economic impacts as well as environmental impacts in the Dididi village.

In a separate study by Jerin *et al.* (2016) at Bagatipara, Natore, Bangladesh, the authors assessed the impacts of clay brick production on the environment and the economy. The study utilised questionnaires to interview the community members residing in the local community were clay brick manufacturing business was being conducted. The questions were designed to analyse impacts of clay brick manufacturing on air, water, soil, vegetation as well as socio-economic conditions. The findings of this study were based on perception of change of resource or condition. From the results, it was noted that there was a decrease in soil fertility and subsequent reductions in crop production. Furthermore, the authors reported that dust covering trees around the community, from the nearby clay brick manufacturing sites.

Like a study by Jerin *et al.* (2016) on the environmental impacts of clay brick production, Rajarathnam *et al.* (2014) conducted a study assessing environmental impacts related to air pollution from kiln clay brick production in India. More specifically, the study analysed emissions of SO2, CO and CO2 in and around the areas near the study area. The authors also compared different types of kilns, in relation to their performance with regards to pollution. It was reported that, zigzag and vertical shaft brick kilns showed better performance in terms of emissions over the traditional kilns. The results of the study suggest that the replacement of traditional technologies with zigzag or vertical shaft brick kilns or other cleaner kiln technologies are less harmful to the environment.

Further to a study by Rajarathnam *et al.* (2014), Kulkarni and Rao (2016) estimated carbon footprint of clay bricks manufactured using different types of kilns in Karad, District Satara, Maharashtra (India). The field survey was conducted to collect the data about use of soil, fuels and water and its transportation. The average carbon footprint of the bricks manufactured in the clamps of Karad was recorded at 195 g CO2/kg of fired brick and 162 g CO2/kg of fired brick respectively. The statistics from the study showed the amount of carbon footprint due to combustion of biofuels and transportation of raw materials.

The study by Khan *et al.* (2019) assessed the impact of the brick kilns industry on the environment and human health in Pakistan. More specifically, the authors, identified and ranked the emissions from brick kilns based on their harmful impact on human health and the environment, (ii) ranked three types of brick kilns (Traditional Brick Kilns, with coal as a fuel, Traditional Brick Kilns with rubber as a fuel and Contemporary Brick Kilns, technologically advanced brick kilns) based on their impact on human health and environment. The study used questionnaires distributed to the professionals and experts of EPA of Punjab and Khyber Pakhtunkhwa provinces of Pakistan. The data regarding the impact of brick kiln emissions on human health and the environment was collected from 22 professionals which include 45 % medical doctors, 49 % environmental professionals and 6 % academics. The data for selecting the brick kilns based on emissions were collected from 25 experts which include 73 % EPA professionals and 27% academics. Results from the study showed that CO2, CO and SO2 have the most harmful effects on the environment. In addition to that, carcinogenic dioxin, SO2 and Particulate Matter(PM) were found to have adverse effects on human health."

Looking at the environmental degradation due to clay brick manufacturing like the aforementioned studies, Khan *et al.* (2007) assessed the degradation of agricultural soils due to brick burning in selected soil profiles i.e. (soil around brick kilns) and unburnt (agricultural land) soils in the western part of Bangladesh. From the study it was noted that the pH values of the unburnt soils increased as a function of the soil depth, while decreased for the soil profiles in other regions. Burning of soils significantly decreased the average pH values of soils by 0.4 pH units but extraordinarily increased the average EC values from 0.26 to 1.77 mS/cm (592 %). The average sand content of the soil profiles increased by 330%, while the silt and clay contents decreased by 49 and 40 %, respectively. The average losses arising from the burning of agricultural soils amounted to 63% for organic matter. This huge loss through the burning of 1 m deep soil profile was noted to have reduced the crop production and also polluting the associated environment and atmosphere.

Lastly, Le *et al.* (2010) analysed brick kiln emission impacts on air quality. The authors reported that emissions of individual air pollutants varied significantly between the course of clay brick manufacturing activities. It was recorded that, on average emission factors per 1,000 bricks were 6.4–12 kg of CO, 0.5–6 kg of SO_2 and 0.6–1 kg of particulate matter (PM). PM emission size distribution in the stack plume was determined using a modified cascade impactor. Obtained emission factors and PM size distribution data were used in the simulation study using the Industrial Source Complex ShortTerm dispersion model. The model performance was successfully evaluated for the local conditions using the simultaneous ambient monitoring data. The authors reported that SO_2 was the most critical pollutant, by exceeding the hourly National Ambient Air Quality Standards with over 63 km^2/100-km^2 modelled domain in the base case.

2.11 Conclusion

From the consulted literature, it was noted that widespread poverty and inequalities in the world make reducing the negative environmental impacts posed by clay brick production more difficult. To address environmental and human concerns, clay brick production support should be integrated with strategies that leverage balance between environmental, social and economic goals. Where poverty is a predominant challenge, it is necessary to consider issues of affordability. Environmental assessment must include aspects related to the source and amount of energy required to produce clay bricks. Revised case studies in this literature review provides synoptic view of previous studies which are in line with our current study. The selected studies expounded on the similar aspects which our study will focus on, more specifically, small scale clay brick manufacturing and the associated socio-economic impacts as well as environmental issues. It was noted that in different parts of the word, there are numerous challenges associated with the small-scale clay brick manufacturing. The next chapter deals with the methodology of the study outlining the research design data collection analysis strategies.

3. RESEARCH DESIGN AND METHODOLOGY

3.1 Delineation of the Study Area

The study area falls under Thohoyandou town which is situated in the Vhembe district located in the Northern part of Limpopo Province and shares borders with Capricorn and Mopani District municipalities in the eastern and western directions respectively (Figure 3.1). The climate in the study area is subtropical, with mild, moist winters and wet, warm summers. The annual rainfall of the study area is recorded at approximately 500 mm per annum of which about 87 % of the rainfall falls between October and March which is the summer season. The annual temperature ranges from 10 ºC during winter to 40 ºC in the summer period. The Dididi village is adjacent to the Luvuvhu river and the river flows for about 200 km through a diverse range of landscapes before it joins the Limpopo River.

Figure 3.1: Illustration of the study area location which is the Dididi village close to the Luvuvhu River catchment. Photograph inserts (a) and (b) shows the environment of clay brick manufacturing activities in the Dididi village.

3.2 Research Philosophy

Qualitative research typically locate itself within positivism tradition, notwithstanding that it often holds realist assumptions about the world and the contextual conditions Panhwar *et al.* 2017). On the other hand, quantitative research is in contrast with that notion. It identifies itself as rather less evident since it typically provides less consideration to epistemological and ontological assumptions in discussing research findings (Bryman 1984). Mkansi and Acheampong, (2012) postulated that positivism is considered a scientific research paradigm that involves deducing a hypothesis and expressing it in operational terms and examines theory in the light of findings of the study (Hiller 2016; Ryan 2018). Buttery and Buttery (1991) stipulated that positivism is built on hypothetic-deductive approaches established in the natural sciences and accepts that the world exists independently to people. It is concerned with the situation in which the event is occurring. Positivism philosophy is based on the way people experience social phenomena in the world in which they live (Wynn and Williams 2012).

This study utilised positivism research philosophy because of its notion that the social world can be understood in an objective way and the researcher is an analyst who distances himself from personal values, being partial and independent (Krauss 2005). Knowledge gathered through observations is trustworthy, and information is collected by the researcher through data collection. Upon completion of data collection, the results are quantifiable which is a repeatable task. In this regard, the researcher collected data through a questionnaire, which was distributed in the Dididi village. The researcher took into consideration multiplicity aspect, by having multiple respondents (50 respondents) participating in the survey. Figure 3.2 illustrates the research process which was adopted for this study with explanatory notes for each layer below.

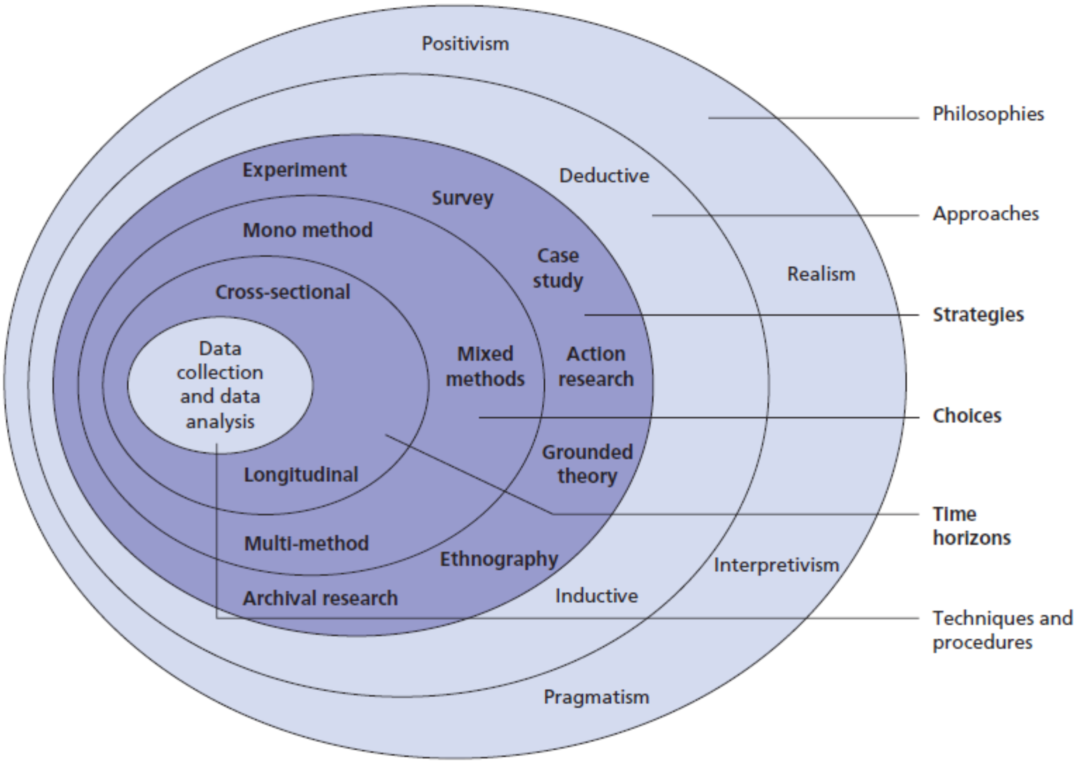

Figure 3.3: The research onion Source: Research Methods for Business Students, (Saunders *et al.* 2009).

3.3 Research Strategy

The study utilised deductive research approach which is typically associated with scientific investigation (Saunders *et al.* 2009). I survey approach which is linked to deductive research was implemented in distributing questionnaires. The researcher, noted previous works through literature review, which are in line with the study as well as reading existing theories of the phenomenon of clay brick production and possible environmental impacts. The approach was chosen because it allows measuring concepts quantitatively and allows generalising research findings (Woiceshyn and Daellenbach 2018).

Furthermore, exploratory research conducted in this study was necessary for seeking new insights employed to evaluate phenomena (environmental impacts of clay brick manufacturing business). It should be noted that exploratory research is essential when the researcher wish to clarify their understanding of the problem articulated in the problem statement. Saunders *et al.* (2009) mentioned that there are different ways to conduct exploratory research. First, the search of literature which is in line with the study, followed by application of interviews and survey during data collection. The recorded data through interviews and survey is presented as report findings which are discussed and put into context comparing with results from previous studies.

3.4 Research design using mixed method

Research design can be defined as a framework of research methods and techniques that are chosen by a researcher during research (Mkansi and Acheampong, 2012). The design allows researchers to home in on research methods that are suitable for the subject matter and set up their studies for success. A carefully planned research design in most cases creates less bias and increases the level of trust in the accuracy of the data collection (Panhwar *et al.* 2017).

This study adopted both quantitative and qualitative approach to obtain the data. These approaches were chosen because it enables extraction of different but complementary data on the same for the problem under study (Panhwar *et al.*, 2017). Furthermore, the purpose of utilising both methods was to bring together the different strengths and nonoverlapping weaknesses of quantitative method through the measurement of water samples. Which is supplemented by the qualitative aspect where interviews were established to derive people's response about the problem under study.

The data was collected using different approaches and techniques from primary and secondary sources. The mixed-methods design utilizes intensive quantitative research assessing the frequency of constructs and rigorous qualitative research exploiting the meaning and understanding of constructs (Creswell *et al.* 2018). By proceeding with both quantitative and qualitative techniques the researcher acquires an in-depth understanding of the feedback from the respondence while offsetting the weaknesses characterized by using each approach on its own (Seawright 2016). The purpose of the research design is to ensure that evidence obtained enables the researcher to effectively address the research problem. Mixed methods have been chosen for this study because:

(i) the researcher can validate or corroborate the results obtained from other methods; and

(ii) the researcher can continuously look at a research question from different angles and clarify unexpected findings and/or potential contradiction.

3.4.1 Qualitative research approach

The qualitative research approach is concerned with subjective assessments of attitudes opinions and behaviours of the respondents (Creswell *et al.* 2018). Qualitative data help researchers in understanding the processes that emerge over time and provides detailed contextual information with more emphasis on the feedback from the participants through quotes. Qualitative methods facilitate the collection of data when measures do not exist and provide a depth of understanding of concepts. It can be transformed to fit the information gathered during the research process and subsequently necessitates manipulations during the whole process (Myers and Avison 2002). This approach allowed the researcher to gain a deeper understanding of the socio-economic problems faced by rural communities in Dididi village tied to clay brick production. The fieldwork allowed for the understanding of the informants through in-depth interviews. Strategic sampling was utilised to gather information from the informants that have characteristics and qualifications that are strategic to the research questions and the theoretical perspectives of the research (Myers and Avison 2002).

3.4.2 Quantitative research approach

Quantitative research is a form of systematic investigation of gathering computable data and performing statistical or mathematical analysis on the data (Caruth 2013; Chowdhury 2015). Quantitative research gathers information from existing or potential respondents using sampling methods. Quantitative research seeks correlation and attempts to control the environment in which the data is collected to avoid the risk of variables, other than the one being studied, accounting for the identified relationships (Chowdhury 2015). This study also adopted the quantitative method as complementary to the qualitative method in mixed methods. More specifically, the Likert scale questionnaire was utilised in the study as well as the open-ended questionnaire for the Dididi villagers. The approaches applied for the collection of data were chosen to satisfy the raised research questions. Furthermore, 50 community members were selected Firstly, as key informants as they possessed knowledge of clay brick manufacturing activities in the village, the despondence sufficiently represented target audience (females, males school children, clay brick manufacturers). It is imperative to have each group represented in the data. Secondly, even with an additional person in the interview, when uncovering new information, or same ideas being repeated. Then there is no new information being provided, hence the number (50 respondents) was chosen as sufficient.

3.4.3 Reasons for mixed methods approach and Time horizon

Combining quantitative and qualitative analysis within a mixed method approach ensures amalgamation of knowledge on water quality and socio-economic impacts of clay brick manufacturing in the study area (Makmor and Ismail 2016). The approach was selected for this study since it allows combined data collection from questionnaires with in-depth interviews, allowing the understanding of local conditions of access to human capital and natural resources and the expectations of individuals about the utilisation of the resources for their livelihood options (Fielding 2012). The mixed-method is favourable when a researcher seeks to continuously look at a research question from different angles and clarify unexpected findings or potential inconsistencies (Malmqvist *et al.* 2019). Moreover, the mixed approach provides a more complete and comprehensive understanding of the research problem (Caruth 2013). The mixed-methods also ensures total representation of experiences, builds questions from one method that materialise from the implications of a previous method and allows evaluation of trustworthiness of inferences gained from one method (Makmor and Ismail 2016). This study utilised a cross-sectional technique which is mostly utilised with questionnaires or survey to collect the data on the subject matter of effects of clay brick production on the immediate environment of Dididi community.

3.5 Measurement instrument and data collection tools

The measurement instrument can be regarded as the method through which research obtains and gathers data from the participants to provide results and conclusions to their study (Knekta *et al.*2019). Measurement instruments are used by researchers to assist in the assessment or evaluation of the subject matter. The instruments are used to measure or collect data on a variety of variables. Measurement instruments guide researchers process of finding and identifying measurement tools essential to gather the results of the subject matter. (Malmqvist *et al.* 2019). Table 3.1 provides linkages between objectives of the study and the measurement instruments as well as data collection tools.

Table 3.1: Alignment of objectives and data collection tools.

Objective	**Aspects**	**Instruments and comments**
1. Determine the levels of water quality parameters (pH, dissolved oxygen, chloride, total dissolved solid, total alkalinity, calcium, magnesium, total hardness, nitrate and electrical conductivity) in the Luvuvhu catchment.	Water quality parameters assessment	Field data collection
2. Evaluate the social impacts of the clay brick production in the Dididi village.	People's perception on social impacts	Open ended and structured Questionnaires
3. Evaluate the economic impacts of the clay brick production on the Dididi village.	People's perception on economic impacts	Open ended and structured Questionnaires

The questionnaire design was guided by the objectives and the research questions of the study, which sought to evaluate the extent of water quality impairment and socio-economic impacts of clay brick manufacturing in Dididi village. The questionnaire approach was selected since it is less costly in terms of money and time spent conducting the study. Moreover, respondents which were involved in the study had a better sense of anonymity. The questions were divided into both structured and open-ended questions and utilised the following scale:

- Strongly Agree {1}
- Agree {2}
- Neutral {3}
- Disagree {4}
- Strongly Disagree {5}

Thus, all the questions (see Annexure A) were related to the topic and theme of the study and were aligned to literature around assessment of the impacts of clay brick production on local communities (Yuan *et al.* 2018; Ashande *et al.* 2019; Aniyikaiye *et al.* 2021). For example, some of questions implemented in the questionnaire, includes the following:

a. *What do you think should be done differently to protect the local environment of Dididi village while the Clay brick making activities continues?*
b. *What do you think about the socio-economic effects of brickmaking to the Dididi village?*
c. *What are the advantages of Brickmaking to the Dididi community?*
d. *What assistance would you require from the municipality as far as the business is concerned?*

It is impractical to study a whole population. Thus, reducing the number of individuals in a study reduces the cost, workload and makes it easier to obtain high-quality information (Jeffs and Ben 1998; Makmor and Ismail 2016). The surveys were conducted in the Dididi village specifically looking at the population which is affected by the clay brick production (directly or indirectly).

3.5.1 Sampling technique

This study adopted a random sampling technique that allows for each member of the population to have an equal chance of selection and contribution to the study. Each sample had an equal probability of being selected, of which will reduce bias in the result of the study to favour any group. This process is randomized; hence the sample reflects the entire population and this allows the data to provide accurate insights into specific subject matters. Ultimately, the researcher did not need to have specific knowledge about the data being collected to have effective results (Mihas 2019). The sample unit was largely the Dididi village community members who are affected by the brick-making activities in the area. The sample size of two individuals from the municipal officials is guided by the fact that the community is very small that does not warranty to have many individuals overseeing the environmental aspects of the area. In addition to that the sample size of 50 individuals was large enough, to gather necessary information for the project.

3.6 Field observation and measurements of water quality parameters

According to Denscombe (2007) observation does not rely on what people say, do or think but on direct evidence that the researcher observes. Observations made in this study helped to clarify aspects not captured through interviews. Informal interviews became an important adjunct to observation when the observer was not sufficiently familiarised with the object being observed (Marshall and Rossman 2006). Observations of the day today activities of clay brick production in the field enable the researcher to have a clear picture of the aspects under study (i.e environmental impacts of clay brick production)

3.6.1 Water sample measurement

Water samples were collected both upstream and downstream Luvuvhu River (approximately 100 m away) (Figure 3.3 insert) in relation to the location of the most clay brick production activities. According to World Health Organization (1993) guidelines for drinking water quality sampling. This study adopted the following aspects:

a. Water sampling points should be selected such that the samples taken are representative of the different sources from which water is obtained.

b. The collected points should include those that yield samples representative of the conditions at the most unfavourable sources.

c. Sampling points should be uniformly distributed throughout the water system, taking population distribution into account.

Figure 3.3: Distribution of sample locations and picture inserts (a) and (b) bottles used for water sample collection.

The water sample were collected using sterilized containers to get un-compromised readings (Vran 2005; Granger *et al.* 2018). This procedure was done to enable quality measurements from the collected water samples (Granger *et al.* 2018). Since the brick makers use this water for cooking and drinking, the suitability of the water for such purposes was assessed by comparing the measured parameters to the limits and associated risks for domestic water as determined by the South African National Standard (SANS). The parameters include the following pH, Electrical conductivity (EC), total alkalinity, Nitrate (NO_3) Orthophosphate (PO_4), Calcium (Ca), Magnesium (Mg), Iron (Fe) and Turbidity Total hardness. The samples were measured at Aquatico laboratories (Appendix 6.2) with 24-hour period.

3.6.1.1 Water pH

Water pH is recognised as a measure of how acidic/basic water is (Atkinson *et al.* 2007). The range of water pH is measured from 0 to 14, with 7 being neutral. Notably, pH of less than 7 indicate acidity, on the other hand whereas a pH of greater than 7 indicates a base. Typically, water pH level is tested using test kit, with indicator drops, and pH test strips (Atkinson *et al.* 2007).

3.6.1.2 Electrical conductivity

Electrical Conductivity is a measure of stream or river water quality (Shivayogimath *et al.* 2012). Each river has relatively constant range of conductivity that, once established, can be used as a baseline for comparison with regular conductivity measurements. Typically, electrical conductivity is measured with a probe and a meter. The voltage is applied between two electrodes in a probe sunk in the sample water (Shivayogimath *et al.* 2012).

3.6.1.3 Total alkalinity

Total alkalinity is a measure of a river's ability to neutralize acids. Alkaline compounds in the water remove H^+ ions and lower the acidity of the water. Total alkalinity is usually measured by combining with the H^+ ions to make new compounds (Boyd *et al.* 2016).

3.6.1.4 Nitrate

Nitrate is a common contaminant found in rivers. When nitrate levels are between 0 ppm to 10 ppm it is considered safe drinking (Boyd *et al.* 2016). Typically, nitrate is determined using the ultraviolet spectrophotometric screening method. For this study the collected samples were taken to the laboratory (Appendix 6.2).

3.6.1.5 Orthophosphate

Orthophosphate is a good measure of total phosphorus in effluent except for the amount tied up in the effluent solids. Since phosphorus molecules tend to attach to the inside surface of sample containers, containers should be washed to remove adsorbed phosphorus (Peacock 2021). The samples were taken to the laboratories for analysis.

3.6.1.6 Calcium

Calcium is generally determined using atomic absorption spectroscopy or inductively coupled plasma atomic emission spectroscopy (Peacock 2021). Furthermore, a much simpler way of measuring calcium is by ionising acid-bound calcium using acid icing pre-treatment. The samples were taken to the laboratory for analysis.

3.6.1.7 Magnesium

Magnesium is a chemical that occurs naturally only in combination with other elements. It reacts with a chromogen to form a coloured complex, and the absorbance which is measured at 620 nm (Bommala *et al*. 2019). The samples of magnesium were taken to the laboratory for analysis.

3.6.1.8 Iron

Iron content is analysed in the range of 0.25 to 15 mg/l. The high iron content method is commonly used to assess the iron content in water samples. Low iron content analysis is an approach which is used for measuring mostly filtered water's residual iron content ranging between of 0-0.5 mg/l.

3.6.1.9 Turbidity total hardness

Water hardness is a measure of the concentration of all the polyvalent cations dissolved in the water it is associated to the dissolved minerals found in water. River's hardness shows the geology of the river and often higher concentrations of iron ions in the water results in a very high hardness degree of the water flowing in the river (Khadse *et al.* 2008). Water samples were taken to the laboratory for analysis.

3.7 Data analyses and interpretation

The first stage of analysing data is data preparation, where the aim is to convert raw data into something meaningful and readable. This was followed by data validation, which was used to find out, as far as possible, whether the data collection was done as per the pre-set standards and without any bias. Data editing or data cleaning was conducted on the data sets that might have included errors. For instance, errors in completing some fields incorrectly or skipped them accidentally. To make sure that there were no errors, the researcher conducted basic data checks, and edited the raw research data to identify and clear out any data points that may hamper the accuracy of the results. This process helps researchers summarise the data and find patterns in the responses. Descriptive statistics provide absolute numbers and do not necessarily explain the rationale or reasoning behind those numbers.

A number of numeric quantitative analysis where conducted using the Statistical Package for Social Science Software (SPSS). For example, descriptive statistics that provide absolute numbers and do not necessarily explain the rationale or reasoning behind those numbers. Descriptive statistics are most helpful when the research is limited to the sample and does not need to be generalized to a larger population.

With Likert scale data the researcher did not measure the mean as a measure of central tendency since it has no meaning. The researcher displayed the distribution of responses i.e. (% that agree, disagree etc) using graphs. The scores of responses were tabulated into frequencies. The regression model was not conducted on all the questions, since it would have caused multicollinearity issues. Additionally, the study used a small sample, the researcher had to decrease the number of variables in the model. Cronbach's alpha was tested in the study to measure the internal consistency or variables, or to establish if the questions effectively measure the concept (effects of brick manufacturing activities to the Dididi community). The test is calculated as a function of the number of test items/questions and the average inter-correlation among the items/questions. It is considered to be a measure of scale reliability. It should be noted that as the average inter-item correlation increases

Data for physicochemical parameters of water samples were presented as mean values and analysed using descriptive analysis. Regression analysis was carried out in order to know the nature and magnitude of the relationship among various physicochemical parameters.

3.8 Ethical considerations

Ethical principles require that the researcher to show honesty and accuracy in their research (Bryman and Bell 2007). Most importantly the researcher sought for permission to conduct the research form the responsible authorities before conducting the survey. Furthermore, each participant was informed of the task of which they were asked to give concert for participating in the survey. Research participants should not be subjected to harm. The protection of the privacy of research participants were ensured. Qualitative research often involves a close relationship between the researcher and the informants. As a result, the ethical aspects associated with the different phases of the research process must be reflected upon. In studies that entail a close relationship between the researcher and the informants, such as in-depth interviews, the handling of personal information requires ethical guidelines (Bryman and Bell 2007).

3.8.1 Confidentiality

Information which was collected from the respondents was kept confidential. Aspects which indicate that the researcher has to make the informants anonymous when the results of the research are being presented (Del Boca and Noll 2000). The researcher has to be careful when handling the data from the interviews so that the identity of the informants cannot be exposed. It also encompasses that re-use of the data material cannot happen unless the informants have given their consent. The question of replicating a research project is linked to a positivistic research logic that accentuates neutrality as a relevant research ideal, and where the results should be independent of relations in the research situation.

3.8.2 Permission

The researcher's proposal was first submitted to the ethical approval by the UNISA college of Agriculture and Environmental Science and the ethical clearance was provided by the ethics committee before commencing with the research project (see Appendix 6.3).

3.9 Validity, reliability and trustworthiness

Validity determines whether the research measured and analysed what was described in the purpose of the study in line with the objective of the study. Reliability is linked to the findings of the study, in ensuring repeatability of the study. The methods used for quantifying different variables in this study should be able to be replicated by a different researcher. Thus, reliability ensures credibility of the study, which demands consistency. In the case of qualitative results that cannot use quantified variables as evidence there is a need to ensure trustworthiness and credibility of the respondents (Caruth 2013).

The researcher took heed of the transferability aspect of the study, in the sense that the work output can be transferred and applied to other context giving similar results. The research has detailed information and used purposive sampling in selecting individuals who are one way or another affected by the clay brick production. The research work was done in a manner which ensures stability and consistency in the process of integration between data collection data analysis and the presentation of the results. This was done using triangulation and clear explanation of how the data collection was conducted. The records were maintained in a transcript and field notes for review from the reviewers from UNISA.

Trustworthiness is the degree of confidence in data analysis and the methods used in data collection to ensure quality of the research. The approach taken to adhere to this aspect is that the researcher ensured credibility, dependability, confirmability and transferability of the research. Procedures were taken to ensure that the data is free from misinterpretation by engaging with the respondents.

3.10 Limitations

The reliability “of survey data may depend on the following factors: Respondents may not feel comfortable providing answers that present themselves in an unfavorable manner. Respondents may not be fully aware of their reasons for any given answer because of a lack of memory on the subject, or even boredom. Surveys with closed-ended questions may have a lower validity rate than other question types. Data errors due to question non-responses may exist. The number of respondents who choose to respond to a survey question may be different from those who chose not to respond, thus creating bias. (Leedy and Ormrod 2015). Survey question answer options could lead to unclear data because respondents may interpret certain answer options differently. To overcome this, the researcher will try as much as possible to encourage key participants to participate by ensuring their confidentiality and anonymity (Leedy and Ormrod 2015).

Another key aspect related to data collection from respondents is the reactivity of the participants. Some participants maybe familiar with the research and maybe less open in their responses. This prompts their responses to be affected and will lead to some sort of bias. In order to counter this problem, the researcher sought for experienced research assistants in an effort to guarantee open ness and concise, honest information exchange between the researcher and the participants.

3.11 Conclusion

This chapter described the nature of information required to address the research problem and the methodology used to conduct this study. Considering that the necessary information will be based on peoples’ experiences and on what can be observed in daily life, both qualitative and quantitative approaches were applied. The data collection methods involved, observation, interviews and participation in practical work and water sample collection from the field. The application of these data collection methods in local communities was reasonably successful. The description of the data collection methods helped to understand that they are suitable for acquiring the necessary information. After the fieldwork was finished the collected data were analysed. The way the information was collected also influenced the analyses in that the researcher considered the different contexts in which he conducted the fieldwork. The findings emanating from the analyses are presented in the next chapter.

4. RESULTS AND DISCUSSION

4.1 Introduction

This Chapter provides the results of the analysis of the interviews conducted in the study as well as the water quality samples collected from the field data analysis. The findings were explained in relation to the information from similar research outputs. This was done by providing the description and graphical representation of the results from the analysed data. The Chapter begins by presenting the descriptive statistics of the analysed data. This was followed by presentation of the findings from the interviews. The results of the study answered the research questions designed for the study which includes the following: does the brick-making industry in Dididi village change water pH, conductivity, and other parameters to non-compliance levels as stipulated by Department of Water and Sanitation? does the brick-making industry have an impact on social factors (school dropouts, low income, father absentee's, crime and violence)? does the brick-making industry have an impact on the economic situation of the people in the Dididi village?

4.2 Descriptive Statistics

Demographics of the population sample (Individuals working in the clay brick manufacturing business) by gender (n = 50) is presented in Figure 4.1. The male population was more than the female population, with the proportion of 60% for the former compared to the later which was 40%. From the statistics it is noted that the male population is higher than the female population, which is attributed to the fact that, males are highly active in clay brick manufacturing business, which is rather physical in nature, thus there are generally fewer females. The output of the survey shows that the male population was higher than the female population working in the clay brick manufacturing industry. These statistics can be attributed to the physical nature of the business. This assertion has been echoed by Wayessa (2020) who conducted a study on the dilemma of rural artisan women in southwestern Ethiopia. Mukwevho, *et al.* (2014) postulated that there are more males in the brick manufacturing industry since there are not bothered by the risk of the industry in their study of the effect of employees' working conditions in the burnt brick manufacturing industries in the Vhembe District of Limpopo Province, South Africa."

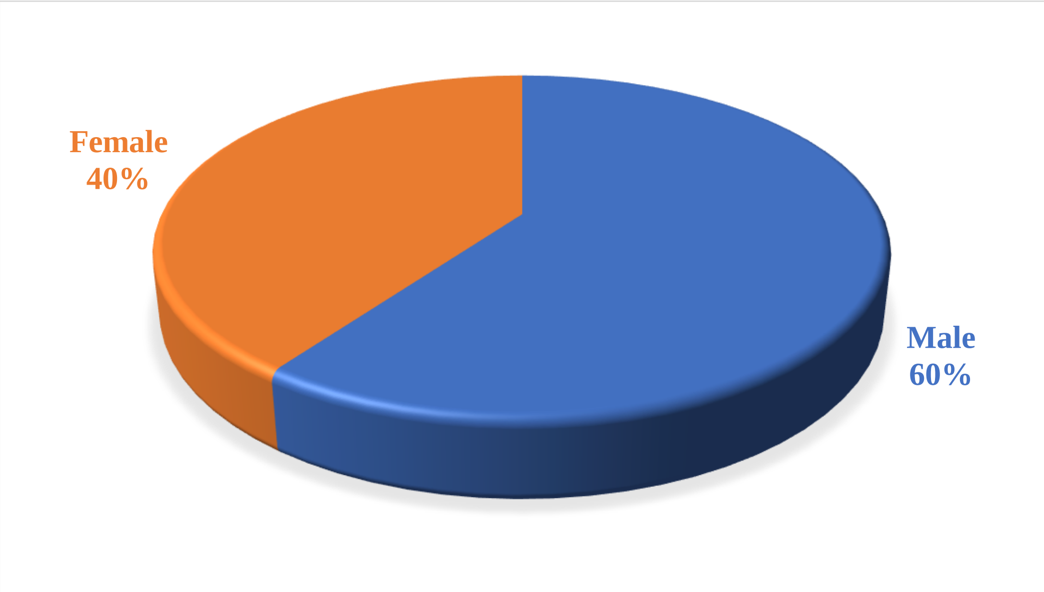

Figure 4.1: Illustration of the total population size by gender.

Furthermore, majority of the males can cut down trees, which is an essential source of energy for the kilns. The results of the study also showed that there is increased over exploitation of wood in forest areas and the wild or uncontrolled felling of trees. More households in the rural areas expect men to be breadwinners, thus if they cannot secure employment, the obvious source of employment is found in the clay brick manufacturing industry. At the same time, it is expected that most women in the rural areas are mostly involved in the farming activities. Due to reduced soil fertility and limited rainfall due to climate change, women resort to small-scale garden projects which leaves men to be heavily involved in the clay brick manufacturing industry.

The survey was also categorised according to age group. From the results (Figure 4.2) the largest age group in the clay brick manufacturing business was dominated by young adults in between 18 and 25 years with 18 people out of the total 50 (36%). Of the 18 young adults, it should be noted that all the respondents dropped out of school to venture into clay brick manufacturing. This was followed by the 26 to 36 age group which contributed to 28%. 37 to 47 age group had a proportion of 15% of the respondents which were interviewed in the study in relation to clay the brick manufacturing business. The age group between 48 and 58 years had a population proportion of 12% and the oldest population age group, i.e., greater than 59 years had a proportion of 6% of the interviewed population.

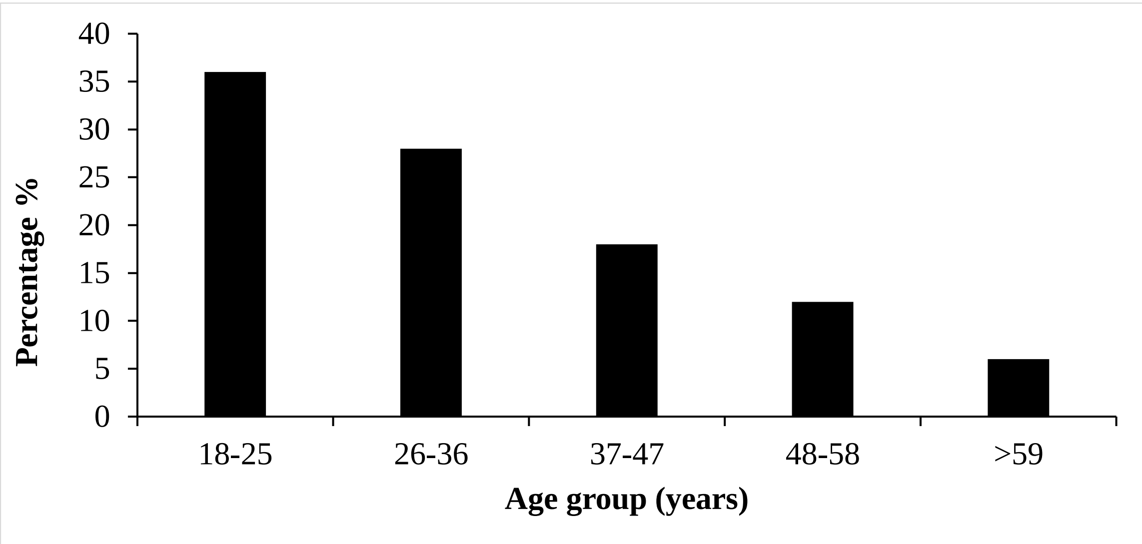

Figure 4.2: Illustration of the Age group of the sample population.

From the survey report (Figure 4.3) the largest proportion (32%) of the individuals involved in clay brick production had Matric level of education. The highest number of this proportion can be attributed to the fact that, most of these individuals do not seek to advance their education level after completing matric education. A category of individuals with "Other" level of education had a proportion of 32% which was equally the highest proportion. Individuals with Masters, Degree and Diploma education also contributed to 10% of the population sample of people involved in clay brick production. The lowest proportion of 6% was recorded from individuals with Honours level of education.

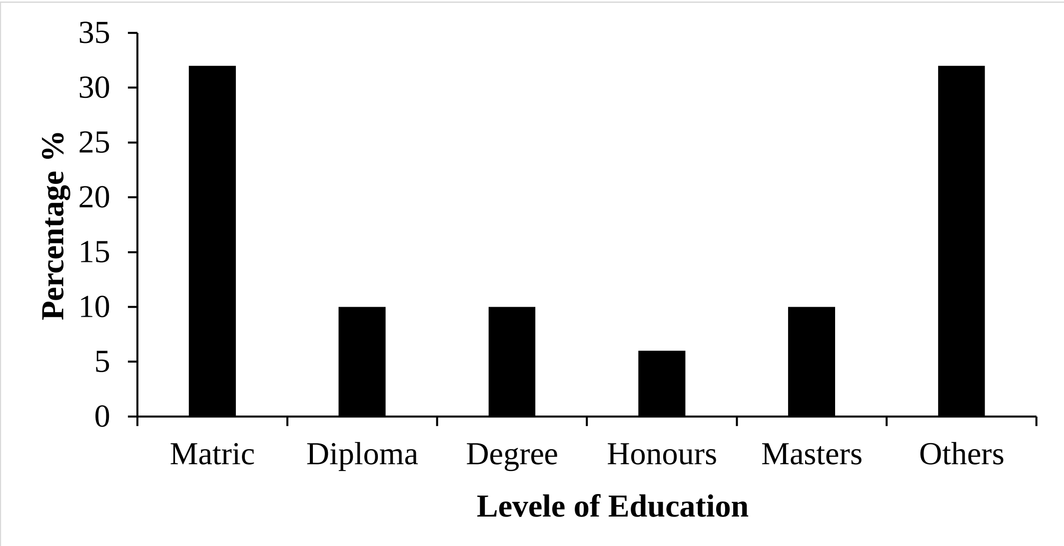

Figure 4.3: Representation of the Qualifications of the population sample.

Furthermore, descriptive statistics were calculated for the variables (10 questions) analysed in the study. Results from Appendix Table 6.4 shows the highest Mean statistics of 3.1 being recorded from variable Q3 (Brick making results in deforestation). The same variable also recorded the standard deviation value of 1.37 and the variance of 1.88. Variable Q3 recorded skewness value of -0.33 and the Kurtosis statistics value of -1.05. Following variable Q3, variable Q2, i.e., Brick making activities benefit the local's variable recorded the lowest Mean value of 1.16, Standard Deviation 0.37 and Variance of 0.14. The statistics for Skewness and Kurtosis were recorded at 1.91 and 1.72.

Results "showed that, the largest age group in the clay brick manufacturing business was dominated by people of 18 to 25 years. Interestingly results of the education level of the individuals involved in the study shows that more people possessed Matric education, with a population size of 32%. From the output of the study, it can be observed that when people finish matric education, they are actively involved in the clay brick manufacturing industry. There are a number of reasons which can be attributed to the large percentage of this age group in the business, which includes: (a) lack of other job opportunities, lack of money to progress with education, pressure from parents to look for employment as well as peer pressure etc. Interestingly the highest proportion (34%) of the respondents were neutral, with 18% of the respondents reporting that they disagree that clay brick manufacturing leads to school dropouts. Overall, majority of the respondents could not confirm whether school dropouts are related to the business of clay brick production/manufacturing.

4.3 Impact of clay brick production in the Dididi village

Question 1 from the study was as follows "*Does brick making have negative impact on the water quality*" Results presented from Figure 4.4 shows that the majority of the respondents (54%) interviewed strongly agreed with the notion that brick making has negative impacts on the water quality. This could be attributed to the fact that these individuals had noticed disposal of chemicals or floating substances in the nearby river channel. 14% of the respondents also mentioned that they agree that brick making has negative effects on water quality. On the other hand, 2% of the respondents mentioned that they disagree and 18% strongly disagree. Interestingly 5% of the respondents were neutral. Overall, the results show that most respondents realise that brick-making activities leads to compromised water quality.

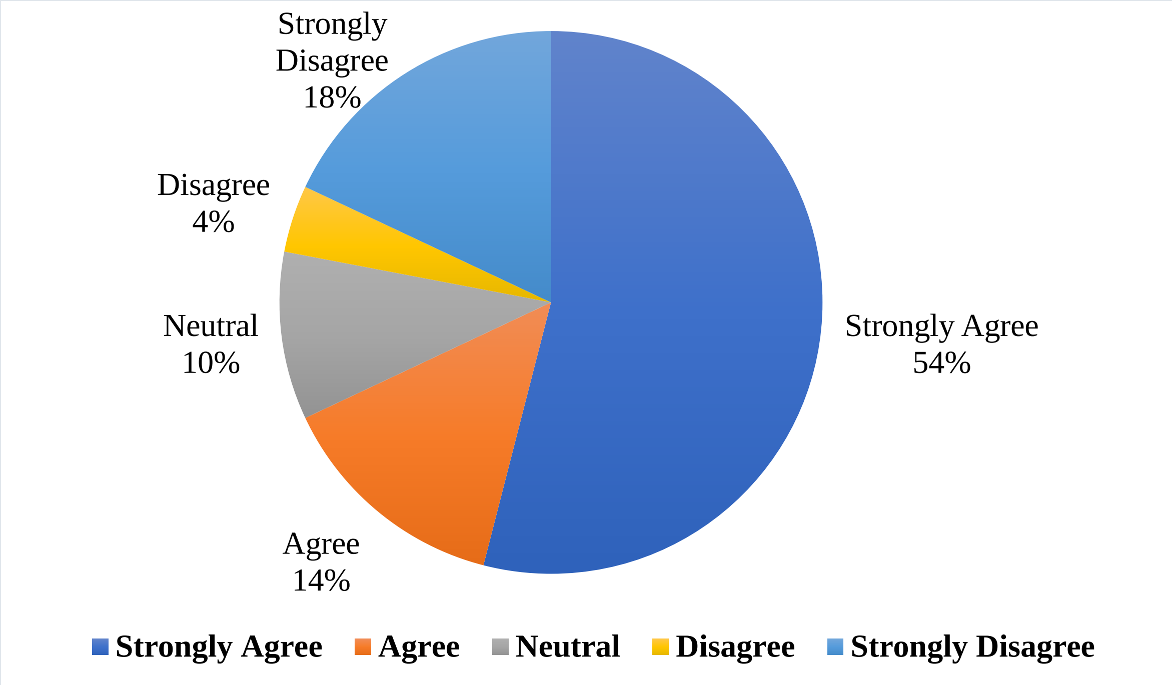

Figure 4.4: Respondents' perception on water quality in the village.

Question 2 on the survey, was set to establish people's perception on the benefits they retain from the clay brick manufacturing business. "*Brick making activities benefit the local community of Dididi Village*". Most of the respondents (84%) reported that they agree that clay brick making activities yields benefits, with only 16% of the respondents reporting that they strongly agree (Figure 4.5). These results shows that the community can realise and are enjoying the benefits of the clay brick manufacturing business with a few individuals having reservations of its benefits to their immediate well-being. The manufacturing and production of clay bricks, although socially acceptable and economically viable "in rural areas, is not environmentally friendly and this practice does not promote sustainable development. Notably, majority of the respondents (54%) interviewed reported that they strongly agree with the notion that brick making has negative impacts on the water quality. The same conclusion was reported by Khan and Vyas (2008) who conducted a study analysing the impact of brick industries on environment and human health in Ujjain City India.

It should be noted that 84% of the respondents reported that there is reward in clay brick manufacturing. This assessment shows that the community can realise the benefits of the brick manufacturing business with a few individuals having reservations of its benefits to their immediate well-being. Output from this study agrees with Ashande *et al.* (2019) who conducted a study assessing socio-economic and environmental impacts of clay brick manufacturing in Nord Ubangi Province, DR Congo. They reported that profit from the manufacture of clay bricks is estimated at approximately US$522 and the money is mainly used for school fees children's schooling, health care and other daily needs.

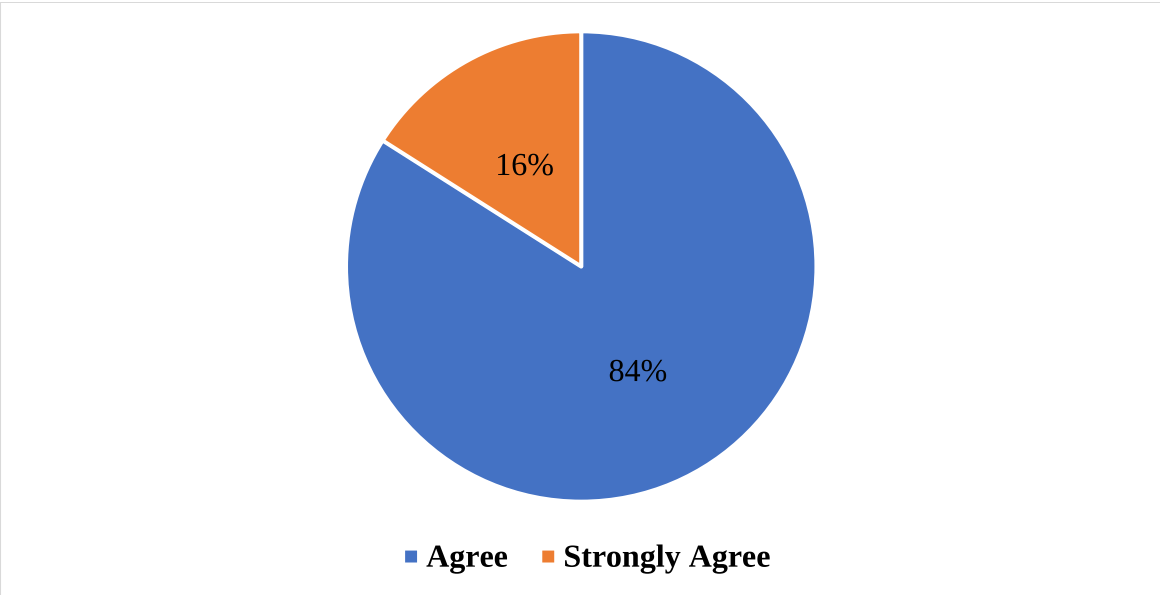

Figure 4.5: Benefits of clay brick manufacturing.

Question 3 of the survey sought out to establish respondents' perception on the effects of clay brick manufacturing business to deforestation. "*Cutting of most trees around the Dididi village is as a result of the brick making activities around*". The results of the survey (Figure 4.6) showed that 22% of the respondents strongly agree, 6% of the respondents agree with 28% being neutral. Conversely, 28% of the respondents reported that they disagree and 16% reported that they strongly disagree. The results show that the majority of the respondents were equally split at 28% with the either pf the population sampled with highest frequency being neutral and the other, resulting in strongly disagreeing.

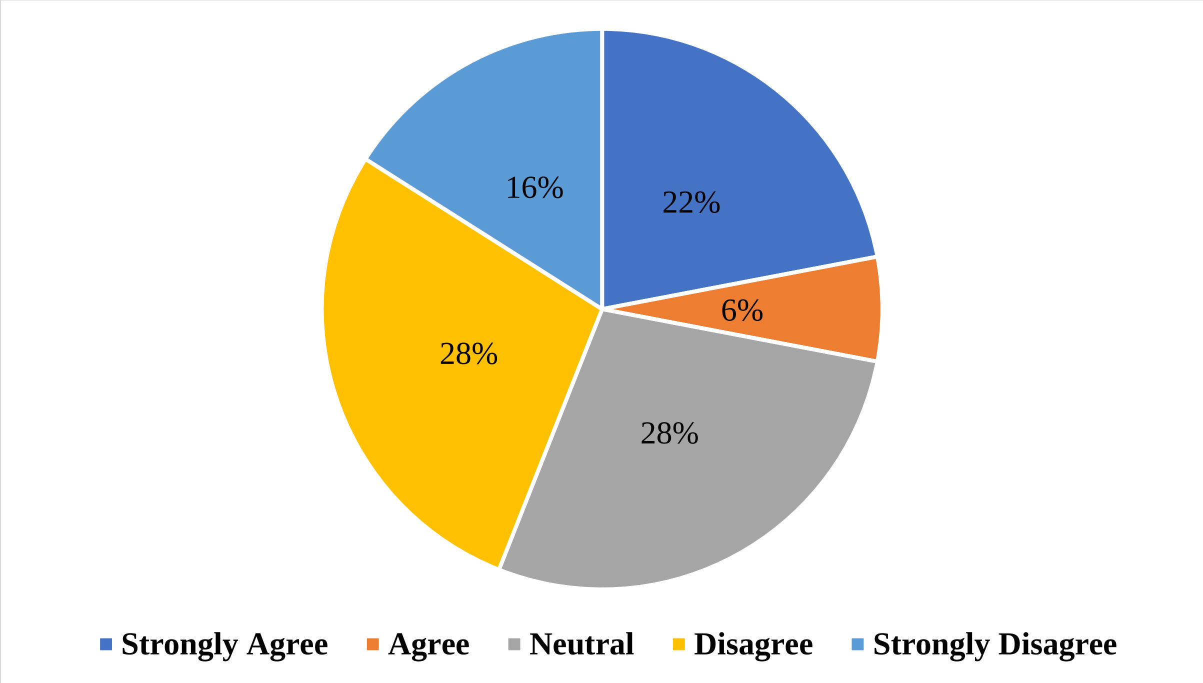

Figure 4.6: Effects of clay brick manufacturing on deforestation.

In terms of the effect of clay brick manufacturing to deforestation, results of the study showed that 22% of the respondents strongly agree the manufacturing of brick leads to deforestation, however 28% being neutral. 28% of the respondents reported that they disagree. The results show that the respondents were equally split at 28% with the being neutral and the other population strongly disagreeing. Comparatively, to Ashande *et al.* (2019) who deduced that, the level of education of the respondents does not positively influence their behaviour towards the environment. This might be related to the output realised in our study.

Air pollution is an atmospheric condition in which hazardous substances can cause undesirable effects on the environment. These substances include gases, particulate matter, radioactive substances etc (Ferdausi *et al.* 2008). These pollutants include a wide range of incomplete and complete combustion products emitted during the brick firing process. They originate from both the fuel used for brick firing and the raw brick materials. All the brick kiln operations that are from digging of earth to unloading of fired bricks from the kiln are accompanied by generation of dust which results in the whole nearby/surrounding and workplace dusty. Air pollution in brick kiln is produced both through the stack emission as well as the fugitive emission such as during charging of fuel, crushing of coal, clay excavation, loading and unloading of bricks, laying and removal of dust/ash layer over brick setting, cleaning of bottom of trench/side flues etc. Air pollutants after being discharged from the chimney are carried forward by the wind and expand in the dispersion.

Unloading of fired bricks from the kilns generate lot of dust. This includes the ash covered at the top and coal ash formed during the burning of bricks. Another major source of dust in work place is the dust blown by wind. Since all ash and dust present on the kiln top, along the kiln wall and adjoining passages are fine and uncovered, these are easily blown even by minor wind resulting in excessive dusty conditions. Air quality is an important environmental resource and its deterioration has many serious impacts on human wellbeing. the urinary system, and the digestive system (Nilsson 2015).

Though “the brick kiln air pollution affects the public generally, workers are the class more prone to health hazards than any others since they are exposed to high concentration for extended period. In the study area brick kiln workers are exposed to these hazards in an extensive way since they are working and living only a few meters away from the ignited and emitting kilns. The houses of the workers are located directly at the sites of the kilns and as there are whole families living there, it can be assumed that also their children are affected. Workers engaged in different activities of brick manufacture such as brick making, loading and unloading in kiln, coal crushing fuel charging etc. are under various thermal and physiological stresses due to extremely unhygienic conditions prevailing on selected brick kilns. During survey it is found that the entrepreneurs have not taken any precautionary measures in order to protect the workers from the ill-effects of particulate and gaseous pollutants.

Apart from air pollution the brick industry also consumes large quantity of top soil. Soil quarrying activities by the brick kilns causes serious damage to agricultural land. Carrying soil from different sources to the brick industries assimilates dust particles in the atmosphere and vegetative cover in the surrounding areas. Soil quarrying, generates solid wastes, and it causes water management problems, water logging, open holes become safety hazards for the local animals and people etc. Soil application of brick kiln dust at lower levels increased plant growth and yield of plants.

Question 4 of the survey assessed the respondents' perception on whether the community rely on clay brick manufacturing business for their subsistence, or it is used as supplementary. "*Most of the households in Dididi Village are dependent on the local brick-making activities for income*". Figure 4.7 results showed that majority of the respondents, i.e., 62% of the population strongly agree with the notion that most people rely on brick manufacturing, 24% of the population reported that they agree. Interestingly, only 14% of the population were neutral. From the result it can be deduced that the Dididi villagers rely heavily on the clay brick manufacturing as their source of income. This is because of scarcity of jobs as well as people moving from agricultural production with recent loss in crop yields attributed to changes in rainfall patterns.

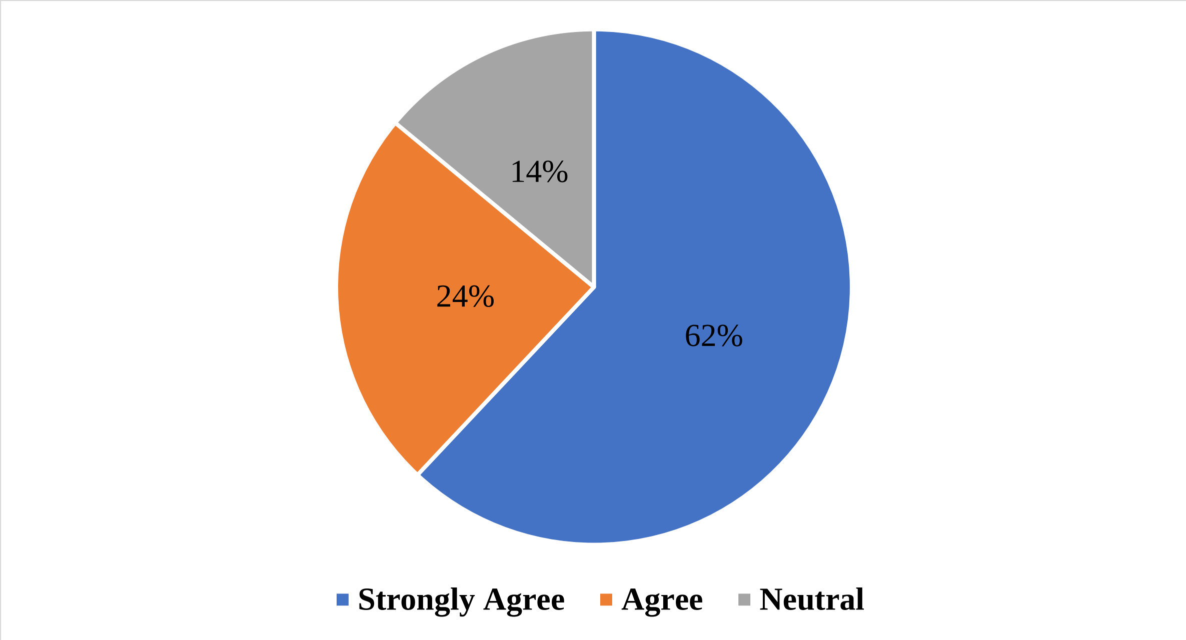

Figure 4.7: Community’s dependence on brick manufacturing.

Figure 4.8 present results of the survey on whether the respondents believe that the clay brick manufacturing business leads to soil erosion. It was noted that majority of the respondents (36%) strongly agree that the clay brick manufacturing activities causes soil erosion, 34% of the respondents agree. Additionally, 20% of the respondents there were neutral. In contrast, only a few respondents reported that they disagree (6%), with 4% of the respondents reporting that they strongly disagree. Although the community continue to engage in clay brick making activities, the result of the survey shows that, most of the individuals acknowledge that it leads to land degradation in the form of soil erosion.

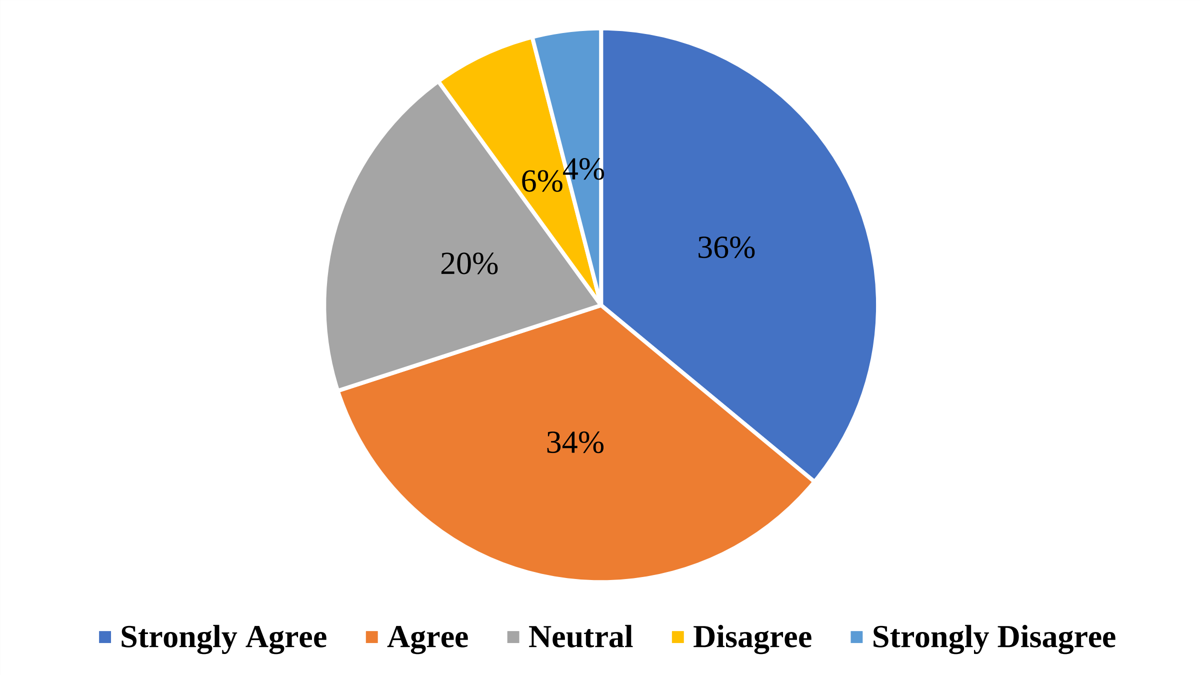

Figure 4.8: Does brick manufacturing lead to soil erosion.

The available nutrients present in brick kiln dust were beneficial up to a certain level but that at larger concentration they were toxic and prevent to plant growth. The removable of top layer removes the organic material from the soil. The infertile soil reduced the capacity of production. The traditional mode of production system not only reduced the production of crops but also it raises the amount of expenditure. The traditional method of making bricks by hand requires good quality clay. This good quality clay is also used for raising various crops. In hindsight, this could also be to some extent related to the community members of Dididi village resorting to clay brick manufacturing instead of crop production. The brick manufacturers of this area use top layer of soil as raw material by digging up the earth in the nearby area of the brick industry either from the good agriculture land or marginal land. These soils are taken on lease from the farmers or villagers of the area.

The brick loam quarrying has another major impact on soil nutrients, which is usually unseen in the quarried lands. Loss of soil fertility through brick production was reported from different regions in Bangladesh, where the same methods for topsoil extraction for brick production were used (Khan *et al.* 2007).

In Dididi village the rich agricultural topsoil is quarried away for brick making, leaving behind the sub-soil, lack of nutrients. Moreover, the underground fire in the kiln reduces the surrounding soil moisture and unplanned hacking of the land alters the drainage pattern of the area. One of the major adverse effects on agricultural land by brick soil quarrying is soil erosion. Field surveys showed that topsoil, which is fertile, is carried away by water along the steep slopes caused by soil quarrying. Thus, a huge amount of fertile topsoil is removed from the elevate agricultural land, which lies adjacent to the quarried land. Owner of the quarried land does not bear the cost of inconvenience of the neighbouring affected land. Due to this process the owner of the adjacent land, which is not under quarrying process, becomes bound to lease their land to the brick kiln owners. Such understanding between land owner and brick kiln owner degrades not only land but also the environment.

Water logging is a serious problem in the quarried land around the brick kilns. Water logging means the flooding of land by rain water. It occurs in places where soil quarrying is done. Brick kilns generate waste and sometimes the burrow pits or the huge ditches or the brick manufacturing sites are used for dumping city garbage and solid waste. Water logging is not only the problem of rainy season, but it also occurs occasionally in other seasons. During the field survey it was observed that the lands from where the soil has been quarried became ditches because in such areas the land has not been levelled. During the rainy season these ditches are full of water, and they become ideal breeding sites for mosquitoes and other pests they also become safety hazards to animals.

Question 6 of the survey sought to establish whether brick manufacturing practice enhances local business operations in the community. "*Local cement sellers and transport providers benefit from the clay brick making activities".* From the survey conducted, it was reported that majority of the respondents (32%) strongly agree, this was followed by 18% of the respondents who confirmed that they agree. 4% of the respondents gave a neutral response with 22% of the respondents reporting that they do not agree, whilst 24% of the respondents reported that they strongly disagree (Figure 4.9). Analysis of the survey output shows that majority of the respondents have noted increase in business operations of those who 's business is related to clay brick production. However, a significant number of the respondents reported that they strongly disagree. that the practice leads to business opportunities especially in transport and logistics.

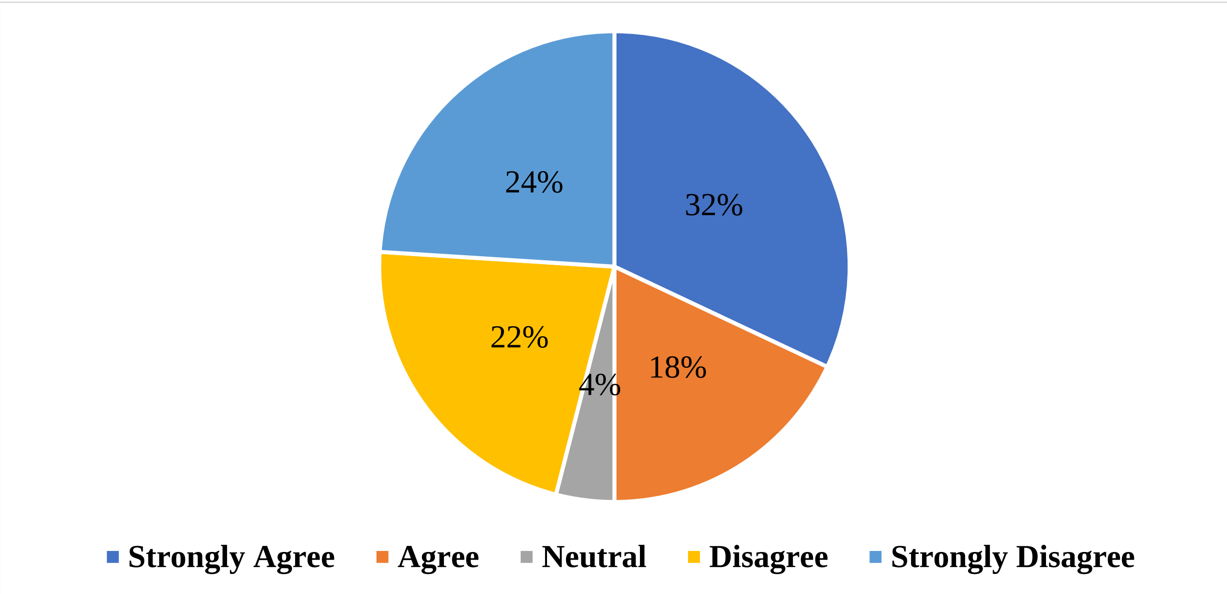

Figure 4.9: Brick manufacturing enhances local business

Figure 4.10 results presents results of question 7 of the study pertaining the environmental degradation caused by brick manufacturing leading to hazardous gullies affecting livestock. The survey results showed that 44% of the respondents reported that they strongly agree, this was followed by 38% of the respondents who also confirmed that they agree. Only 10% of the respondents where neutral, with 8% of the respondents mentioning that they disagree. It can be noted that close to half of the respondents do observe environmental degradation due to their brick making practice. However, because their source of income, they seem not to care about the environmental degradation. Their efforts are focused on livelihood option which provides income.

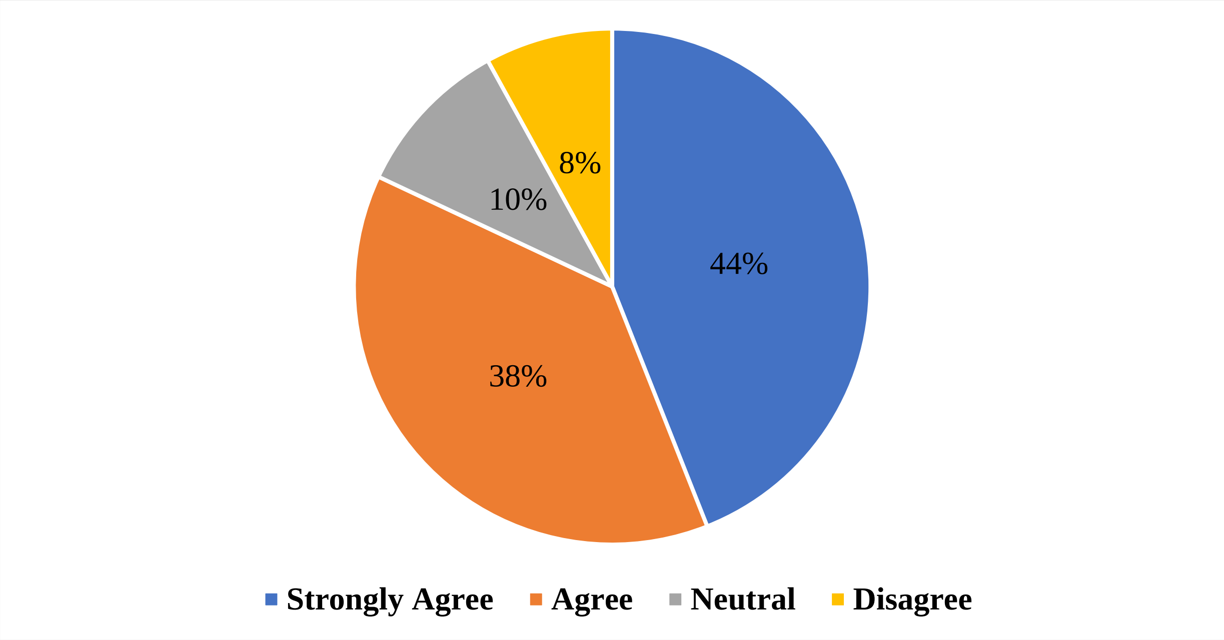

Figure 4.10: Brick manufacturing results in hazardous gullies and holes affecting the livestock.

Figure 4.11 show results of the survey question 8 which was south to establish whether brick manufacturing is expanding or encroaching to fertile arable lands which are meant for agricultural practices. It was observed that, 44% of the respondents strongly agree, with 34% of the respondents reporting that they agree. Interestingly, 20% of the respondents reported that they were neutral whilst only 2% of the respondents reporting that they disagree. The result of the survey shows that the community members confirm that the brick manufacturing activities is expanding to areas meant for agricultural activities.

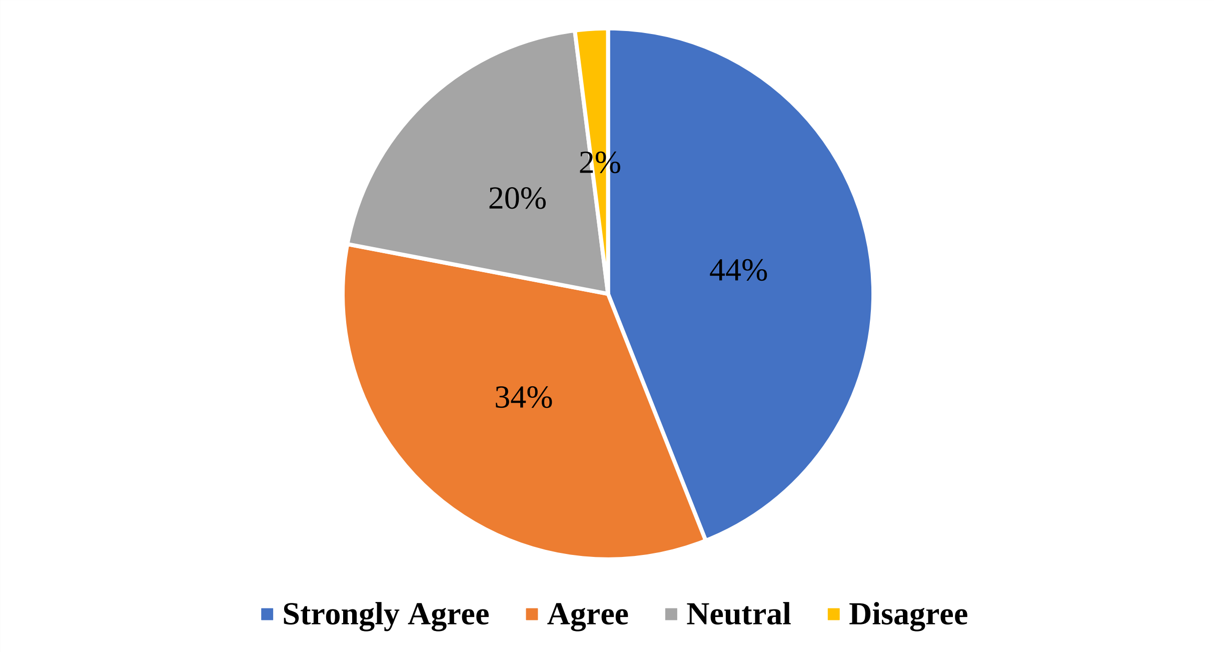

Figure 4.11: Brick manufacturing encroaching on arable fertile land.

Question 9 of the survey sought to establish whether brick manufacturing leads to school dropouts. Figure 4.12 shows results that only 8% of the respondents strongly agreed with the fact that brick manufacturing leads to school dropouts. 28% of the respondents reported that they agree. Interestingly the highest proportion (34%) of the respondents were neutral, with 18% of the respondents reporting that they disagree. 12% of the respondents reported that the strongly disagree. The result of the survey confirms that the majority of the respondents did not want to confirm or deny the notion that brick manufacturing leads to school dropouts.

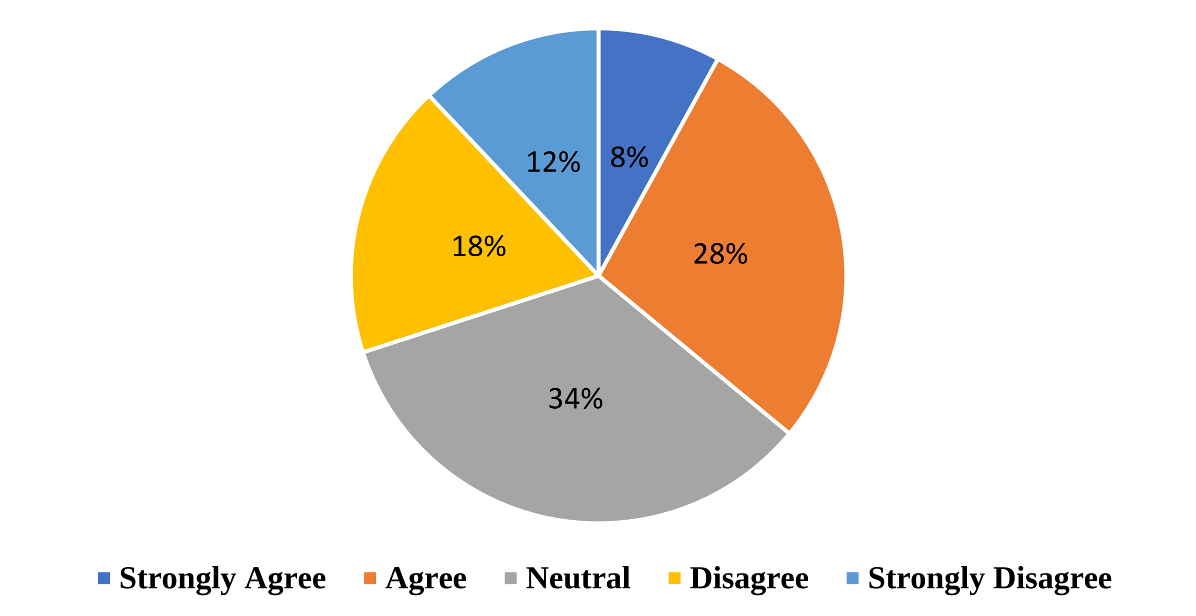

Figure 4.12: Brick manufacturing leads to school dropouts.

Figure 4.13 shows result of the survey question 10 on whether brick manufacturing business has improved socio-economic activities of the community members. It was noted that 40% of the respondents strongly agree that brick manufacturing has improved socio-economic activities of the community. 28% of the respondents agree, with 26% of the respondents reporting that they were neutral. However, only a few numbers of respondents reported that they disagree. The result of the survey shows that the majority think that the brick manufacturing business is improving their socio-economic activities.

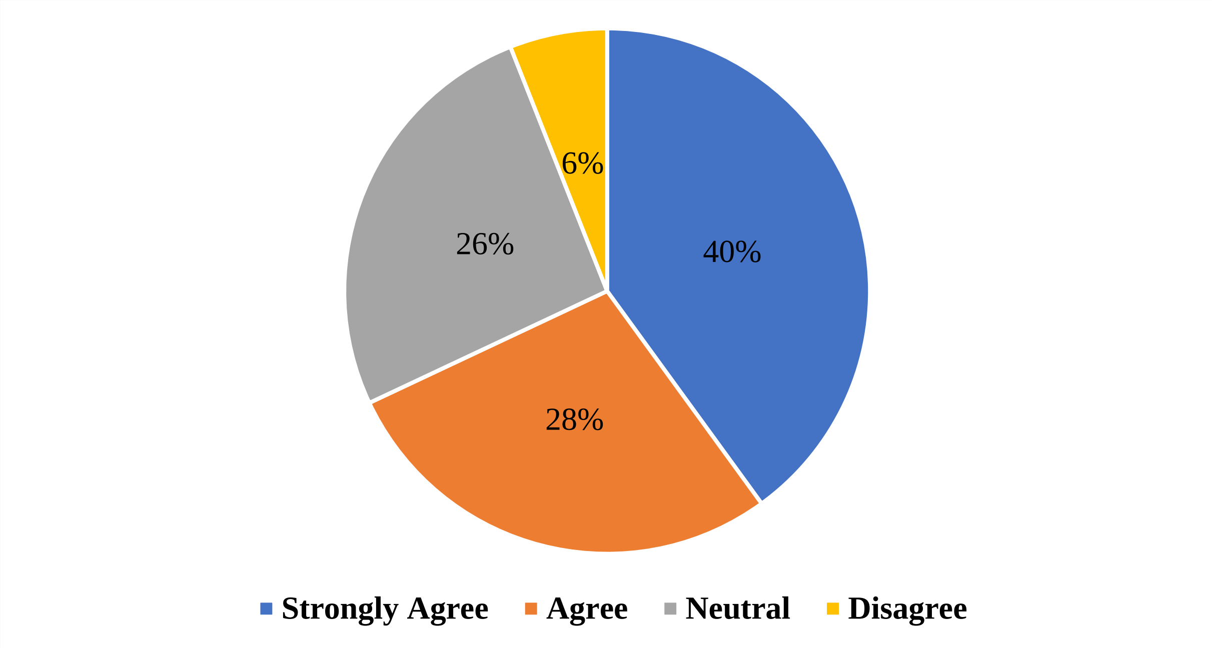

Figure 4.13: Brick making manufacturing improve people's socio-economic activities.

4.4 Measure of internal consistency of variables/survey questions

In measuring the internal consistency of the survey question used in the study, Cronbach's alpha was utilised in the study. The questions were classified according to two categories i.e., positive (Q2, Q4, Q6 and Q10) and negative (Q1, Q3, Q5, Q7, Q8 and Q9). For the positive questions the Alpha value was recorded at 0.4 and for the negative questions the Apha was recorded at 0.1. Since the different sections had questions which reported on the same concepts (effects of brick manufacturing), they are not highly correlated (as we have seen in the Cronbach analysis results above since all the questions in the different sections are measuring the same concept). For this reason, all the questions were included in the regression model since it will not cause multicollinearity issues.

4.5 Regression analysis for Likert questions

The regression analysis was conducted with "Q1" as dependent variable, and the other factors as the independent variables, excluding Q4, Q6 and Q10. The regression results retained $R^2 =$ 0.02 and p-value of 0.8865. Since this value is not less than 0.05 (since we were testing at a

5% level of significance), and thus this model is not statistically significant. This is highlighted by the fact that the R-squared is extremely low and all variables are non-significant. Since the model is not significant, this shows that the relationship between these variables is not significant on population levels. It could be an issue of sample size but the other cause could be that all questions were answered very similarly (almost all the Likert questions were answered by Agree or Strongly Agree) so there is no relationship we can pick up in the data even if we try different models.

The study performed stepwise regression, which shows the best way to determine which of the variables to include in the model. The researcher used stepwise regression with forward selection. Forward selection, which starts with no predictors in the model, iteratively adds the most contributing predictors, and stops when the improvement is no longer statistically significant. Q4, Q6 and Q10 were not significant. The overall model p-value is <0.0001 (statistically significant) which indicate that there is at least one independent variable which is associated with Q1 variable. This means that, at least, one of the predictor variables is significantly related to the outcome variable. The R-squared value of 0.49 indicates that 49% of the variability of the dependent variable can be explained by the selected independent variables.

4.6 Analysis for water samples physicochemical parameters

Physicochemical parameters of nearby river which is the main source of water in the village are presented in Table 4.1. The pH had consistent values comparing the upstream and the three section in the range of 8 pH. According to the Department of Water Affairs and Forestry (1996), there are no significant effects on health due to toxicity of dissolved metal ions in the range between 6.0 - 9.0 pH. From the results the water pH doesn’t fall in the hazardous category. Electrical conductivity was low upstream (14.4 mS/m) and gradually increased along the sampled sections with the maximum of 34 mS/m at section 3. Looking at the stipulated ranged from Department of Water Affairs and Forestry (1996) guidelines, no health effects are expected from the river source which has water conductivity values < 45 mS/m. Total alkalinity increased from 39.6 mgaCO3/l to 130 mgaCO3/l from different water collection points. It should be noted that chemical corrosion may occur when the alkalinity is low, hence the values extracted from the river stream are in the acceptable range 20-200 mg/l. Nitrate concertation in drinking water is a health concern. Acceptable standards for safe drinking water are concentrations of nitrate at less than 5 mg. Department of Water Affairs and Forestry (1996) stipulate that there are no health concerns when Nitrate is in the range between 0 to 6 mg.

The acceptable standard of the presence of orthophosphate in water is 0.005 to 0.05 mg/l (Table 4.1) from the water sample collected in the study, it is clear to note that the river has acceptable range of Orthophosphate. The consumption of excessive amounts of calcium in drinking water naturally results in diarrhoea. Calcium levels of the water samples collected from the river ranged between 0 to 50 which is a soft category and is not harmful or hazardous to people. Magnesium levels recorded from the water samples (Table 4.1) are within the acceptable range (0 to 30 mg/l). At this level the water has no adverse effects to human use. Excessive ingestion of iron leads to haemochromatosis, that is tissue damage occurs as a consequence of iron accumulation (Department of Water Affairs and Forestry 1996).

The water samples recorded are within acceptable range (0 to 0.1mg/l) of available iron for domestic water use. Turbidity of water is related to clarity, a measure of the transparency of water. Most importantly, micro-organisms are mostly associated with turbidity, hence low turbidity minimises the potential for transmission of infectious diseases. Department of Water Affairs and Forestry (1996) stipulate that the range between 1 to 5 NTU there is no turbidity visible and there would be a slight chance of adverse effects and infectious disease transmission. The Total hardness of water varies and usually ranges from 0 - 1 000 mg CaCO /l. From the study, the Total water hardness ranged between 50 to 150 mg CaCO /l, which is from soft to slightly hard according to the Department of Water Affairs and Forestry (1996).

Table 4.1: Physicochemical parameters analysed in the study.

Locality	Water parameters									
	pH @ 25°C	**Electrical conductivity @ 25°C**	**Total alkalinity**	**Nitrate**	**Orthophosphate**	**Calcium**	**Magnesium**	**Iron**	**Turbidity**	**Total hardness**
	pH	mS/m	mgaCO3/l	mg/l	mg/l	mg/l	mg/l	mg/l	NTU	mg CaCO3/l
Upstream	8.74	14.4	39.6	0.198	0.011	9.84	6.04	n.d	2.56	49
Section1	8.66	28.3	119	n.d	0.015	23.4	12.5	n.d	2.12	110
Section2	8.64	31.6	130	n.d	0.024	27.7	13.2	n.d	2.42	124
Section3	8.58	34	130	n.d	0.017	31.1	13.3	n.d	6.6	132

Appendix 7.2 presents the descriptive statistics of the water parameters used in the study. pH had a Max value of 8.7 and Min value of 8.5, with the Mean and standard deviation values of 8.6 and 0.05 respectively. Electrical conductivity measured at 25°C recorded Max value of 34, Min value of 14 and standard deviation of 7.59. The Nitrate levels for the water in the Dididi village recorded the Max value of 0.19. Total hardness recorded the Max value of 132 with the lowest value of 49. The mean and standard deviations were recorded at 96 and 32 respectively.

Overall, selected parameters show that pH was measured in the acceptable standard range of 6.5–9.5 pH as well as Nitrate was below the acceptable standard of 5 mg/l, (Department of Water Affairs and Forestry 1996). A selected pair of parameters were used in the simple linear regression analysis (Table 4.2). The regression was used as a mathematical tool to calculate different dependent characteristics of water quality by substituting the values for the independent parameters in the equations. The regression analyses carried out for the water quality parameters found to have better and higher level of significance in their correlation coefficient. The R-square were high with the lowest correlation coefficient of 0.96 and the highest correlation coefficient of 0.98.

Table 4.2: Regression equation for some pairs of parameters which have significant value of correlation.

Pair of parameters	**Regression Coefficient**		**Equation**	**R-square**
	A	B		
Total Alkalinity and Electrical Conductivity	4.91	28.30	y = 4.9107x - 28.307	0.97
Magnesium and Electrical Conductivity	0.39	0.62	y = 0.3929x + 0.6234	0.96
Total Alkalinity and Total Hardness	0.85	14.49	y = 0.8529x + 14.498	0.98
Total Hardness and Calcium	4.01	11.46	y = 4.0108x + 11.461	0.98
Magnesium and Total Hardness	10.63	16.01	y = 10.636x - 16.011	0.97

In this study, a detailed physio-chemical was carried out to assess the quality of the Luvuvhu river in the study area. The results of the physio-chemical analysis indicated that the following parameters were highly correlated ($R^2 > 0.96$) includes Total Alkalinity and Electrical Conductivity; Magnesium and Electrical Conductivity; Total Alkalinity and Total Hardness; Total Hardness and Calcium, and Magnesium and Total Hardness.

4.7 Water samples physicochemical parameters

In this study results showed that the water samples physicochemical parameters measured in the study area fell within acceptable standards. For example, pH levels of the water were basic ranging between (6.0-9.0 pH). This could be because when carbonate minerals are present in the soil, the alkalinity of water is increased, keeping the pH of water close to neutral even when acids or bases are added. Thus, there are no hazardous concerns with respect to domestic use of the river. However, residue from brick kilns are the major sources of water pollution which includes running water and underground water. Dey and Dey (2015) analysed the various physico–chemical properties of water pH, EC, and Nitrate. They found that the water temperature in the aquatic system near to the brick kilns increases due to the emissions of heat from the kilns which slightly raise the water temperature in nearby aquatic systems.

Furthermore, in contrast to the study by Khan and Vyas (2008) study who found that the brick kiln waste flows back in the Kshipra river, leading to hazardous effects to domestic water use with increased concertation of calcium in the water. In the study area, measured water parameters were found to be in acceptable standards. However, the brick manufacturers do not keep records of the water usage for brick production as it seems to be an abundant and freely available resource. Out of the selected brick kilns two brick kilns are situated around at least meters away from the Luvuvhu River. Waste water from the sites of these brick kilns contains large quantities of suspended solids. Moreover, the workers of these kilns use open spaces near the river as latrines and urinals causing bad smell and unhygienic conditions, workers also cook their food on site using fire.

5. CONCLUSIONS

The purpose of this work was to assess the socio-economic and environmental impact of the manufacture of clay bricks in Dididi village, Limpopo. The study developed and assessed the results against the following objectives; (a) determining the levels of water quality parameters (pH, dissolved oxygen, chloride, total dissolved solid, total alkalinity, calcium, magnesium, total hardness, nitrate and electrical conductivity) in the Luvuvhu catchment; (b) evaluating the social impacts of the clay brick production in the Dididi village; and (c) evaluating the economic impacts of the clay brick production on the Dididi village.

Observations and data collected confirmed that there are more male workers in the clay brick manufacturing industry in Dididi village than females. The highest age group of workers in the study area showed that, most of the people in the fields are young adults with Matriculation education. From the survey questions it was noted that there are various environmental challenges including soil erosion and deforestation. However, analysis of the water parameters showed that the river does not pose any adverse effects in terms of domestic water use in the study area.

The owners of these brickyards provide jobs and a livelihood for their workers. They supply bricks for the very poor people who build their own houses. They are thus playing an important role in their communities, and are examples of the entrepreneurial spirit that is needed in South Africa to tackle the housing challenge of this country in addition to unemployment. Local governments must play their part as agents for Local Economic Development by supporting these entrepreneurs to formalise their businesses and by giving business-friendly services and helping to empower them.

Due to limited employment opportunities most of the young adults have resorted to clay brick manufacturing as an immediate source of income. One of the main reasons why this practice has been prominent in the study area, is because it doesn't necessarily need any level of skills. As long as people are healthy to perform physical work, they easily start working in the clay brick manufacturing. Furthermore, due to the physical nature of the clay brick manufacturing, majority of the workers are males as noted in the study. Some of the activities, includes cutting down of tree, digging the ground and carrying of sand.

Although the measured water parameters in the river showed that the river source is within the acceptable range for domestic water use. It should be noted that the clay brick manufacturing activities have caused an eyesore to the environment in terms of air pollution from the burning of kilns. Plastics are left floating around the river stream. Continued cutting down of trees to use as a source of firewood has led to the depletion of trees, thus deforestation has been experienced in the area.

In light of some of the concerns raised by the respondents, the responsible authorities need to do more in providing for the community in terms of job opportunities. Furthermore, several respondents mentioned that there is need to for the established clay brick association to teach the community members, good practice of clay brick manufacturing. With regards to this, the Clay Brick Association of South Africa should do more and visit the rural areas of the country to provide support to the clay brick manufacturing business, in terms of funding, education and environmental protection practices. From the views of the respondents, it can be established that it is essential to modernise the rural clay brick manufacturing business by encouraging owners to register as private companies and seek for investment or cooperatives so that they can access any potential government or other funding. This is important as it has potential to semi industrialise the process of brick manufacturing delivering improved profits.

Due to limited scope and resource constrains the study could not cover soil samples and total gross value of income made per brick and understanding about the market, this will be considered on further studies.

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7. APPENDICES

7.1 Questionnaires

This section of the questionnaire refers to the background or biographical information. Although we are aware of the sensitivity of the questions in this section, the information will allow us to compare groups of respondents. Once again, we assure you that your response will remain anonymous. Your co-operation is appreciated.

Please insert X in the block which is most applicable to you. Your responses will be treated as strictly confidential.

1. Gender

Male	Female

2. Your Age Group:

18 to 25 years	
26 to 36	
37 to 47	
48 to 58	
59 and above	

3. Do you work for small-scale clay brick manufacturing?

Yes	No

4. Highest Level of Education:

Matric		Diploma		Degree		Honours		Masters		Other	

This research questionnaire is aimed at Evaluation of clay brick production on water quality and socio-economic status in Dididi Village, Limpopo South Africa

Please insert X in the block which is most applicable to you. Your responses will be treated as strictly confidential.

Questions	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. Brick making in Dididi village have a negative impact on the water quality of Luvuvhu river					
2. Brick making activities benefit the local community of Dididi Village					
3. Cutting of most trees around the Dididi village is as a result of the brick making activities around					
4. Most of the households in Dididi Village are depended on the local brick-making activities for income					
5. Brick making activities leads to soil erosion					
6. Local cement sellers and transport providers benefit from the clay brick making activities					
7. The old abandoned holes of clay brick making areas are dangerous are hazardous to the domesticated animals					
8. Brick making Activities are invading and dominating the fertile agricultural areas/soils					
9. Brick making activities are causing school dropouts					
10. Brick making activities are leading to improved socio-economic conditions of the Dididi villagers					

OPEN-ENDED QUESTIONNAIRES

1: What do you think should be done differently to protect the local Dididi village environment while the Clay brick making activities continues

____

____

____

2: What do you think about the socio-economic effects of brickmaking to the village

____

____

3: What are the advantages of Brickmaking to the community

____

____

4: What assistance would you require from the municipality as far as the business is concerned

____

____

5: What has changed in your household with regards to the fmily member's practice in brickmaking activities

____

____

6: What are the different sources of income for the entire household?

____

____

7: What type(s) of energy do you use in your home for cooking?

8: Has the brick making business done anything positive in solving poverty in the village

9: What are some of the problems people encountered related to the brick making business

10: How do the communities perceive brick making business in relation to environmental degradation?

Thank you for sharing your thoughts with us.

7.2 Water samples

aquatico Laboratories (Pty). Ltd.

ilac-MRA   sanas Testing Laboratory T0685

Test Report			**Page 1 of 1**
Client:	Rabelani Mabogo	**Date of report:**	28 April 2021
Address:	92 Vos street, 33 Bislon North, Sunnyside 0001	**Date accepted:**	20 April 2021
Report no:	103215	**Date completed:**	28 April 2021
Project:	Rabelani Mabogo	**Date received:**	19 April 2021

Lab no:				3418	3419	3420	3421
Date sampled:				18-Apr-21	18-Apr-21	18-Apr-21	18-Apr-21
Aquatico sampled:				No	No	No	No
Sample type:				Water	Water	Water	Water
Locality description:				Upstream	Activity section1	Activity section2	Activity section3
	Analyses	**Unit**	**Method**				
A	pH @ 25°C	pH	ALM 20	8.74	8.66	8.64	8.58
A	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	14.4	28.3	31.6	34.0
A	Total alkalinity	mg CaCO3/l	ALM 01	39.6	119	130	130
A	Nitrate (NO_3) as N	mg/l	ALM 06	0.198	<0.194	<0.194	<0.194
A	Orthophosphate (PO_4) as P	mg/l	ALM 04	0.011	0.015	0.024	0.017
A	Calcium (Ca)	mg/l	ALM 30	9.84	23.4	27.7	31.1
A	Magnesium (Mg)	mg/l	ALM 30	6.04	12.5	13.2	13.3
A	Iron (Fe)	mg/l	ALM 31	<0.004	<0.004	<0.004	<0.004
A	Turbidity	NTU	ALM 21	2.56	2.12	2.42	6.60
A	Total hardness	mg CaCO3/l	ALM 26	49	110	124	132

Table 4.1: Descriptive statistics of the water parameters.

Parameters		**Max**	**Min**	**Mean**	**Std**
pH @ 25°C	pH	8.74	8.58	8.65	0.06
Electrical conductivity @ 25°C	mS/m	34	14.4	25.72	7.59
Total alkalinity	mg CaCO3/l	130	39.6	94.47	37.82
Nitrate	mg/l	0.198	-0.194	0	0.17
Orthophosphate	mg/l	0.024	0.011	0.02	0.00
Calcium	mg/l	31.1	9.84	21.10	8.08
Magnesium	mg/l	13.3	6.04	10.73	3.03

Iron	mg/l	-0.004	-0.004	0	0.00
Turbidity	NTU	6.6	2.12	3.05	1.84
Total hardness	mg CaCO3/l	132	49	96.92	32.58

7.3 Letter from Ethics committee

UNISA university of south africa

UNISA-CAES HEALTH RESEARCH ETHICS COMMITTEE

Date: 09/11/2020

Dear Mr Mabogo

Decision: Ethics Approval from 05/11/2020 to 31/10/2023

NHREC Registration # : REC-170616-051
REC Reference # : 2020/CAES_HREC/121
Name : Mr R Mabogo
Student #: 64077683

Researcher(s): Mr R Mabogo
rabebogie@gmail.com

Supervisor (s): Dr CA Togo
catogo@gmail.com; 012-844-0065

Working title of research:

Evaluation of the clay brick production on water quality & socio-economic status in Dididi village, Limpopo Province, South Africa

Qualification: MSc Environmental Science

Thank you for the application for research ethics clearance by the Unisa-CAES Health Research Ethics Committee for the above mentioned research. Ethics approval is granted for three years, **subject to submission of the relevant permission letter, further clarification and yearly progress reports. Failure to submit the progress report will lead to withdrawal of the ethics clearance until the report has been submitted.**

The researcher is cautioned to adhere to the Unisa protocols for research during Covid-19.

Due date for progress report: 31 October 2021

Please note the points below for further action:

1. Permission from the tribal authority is outstanding – this must be obtained and submitted to the committee before data collection may commence. Furthermore, the

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researcher must submit the permission to access the sampling points as it these are obtained.

2. The researcher is cautioned that there must be as little impact on environment as possible when collecting the soil samples.
3. The researcher has not provided the requested scientific justification for the sample size of 50 village members. There is no information on the number of people in village, how many benefit from brickmaking, or how many are involved in brickmaking, for instance. This information is essential to determine whether the intended gender-breakdown of 50/50 for the sample is acceptable.
4. The interview guide for the officials ask for their race – as this has no relevance to the study it must be removed.
5. More detail is required on the regression analysis. What is the motivation for using this approach? The type of regression model and the variables that will be applied must be stipulated. Furthermore, this information must be included in the revised proposal.
6. The researcher indicates that random sampling will be used, and should then explain the homogeneity of the population units.

*The **medium risk application** was **reviewed** by the UNISA-CAES Health Research Ethics Committee on 05 November 2020 in compliance with the Unisa Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.*

The proposed research may now commence with the provisions that:

1. The researcher will ensure that the research project adheres to the relevant guidelines set out in the Unisa Covid-19 position statement on research ethics attached.
2. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.
3. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the Committee.
4. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
5. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing, accompanied by a progress report.

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6. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.
7. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data require additional ethics clearance.
8. No field work activities may continue after the expiry date. Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.

Note:

*The reference number **2020/CAES_HREC/121** should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.*

Yours sincerely,

Prof MA Antwi
Chair of UNISA-CAES Health REC
E-mail: antwima@unisa.ac.za
Tel: (011) 670-9391

Prof SR Magano
Acting Executive Dean : CAES
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7.4 Descriptive statistics of the questions on the survey.

Descriptive Statistics								
	N	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Q1 Brick making has negative impact on the water quality	50	2.18	1.561	2.436	.963	.337	-.683	.662
Q2 Brick making activities benefit the locals	50	1.16	.370	.137	1.913	.337	1.726	.662
Q3 Brick making results in deforestation	50	3.10	1.374	1.888	-.334	.337	-1.045	.662
Q4 Majority of people rely on brick making	50	1.52	.735	.540	1.052	.337	-.311	.662
Q5 Brick making cause soil erosion	50	2.08	1.085	1.177	.934	.337	.433	.662
Q6 Brick making practice spearheaded local business i.e. transport, building	50	2.88	1.637	2.679	.084	.337	-1.699	.662
Q7 Abandoned gullies and holes are hazardous to livestock	50	1.82	.919	.844	1.031	.337	.365	.662
Q8 Brick making is expanding to fertile arable lands	50	1.80	.833	.694	.618	.337	-.644	.662
Q9 Brick making business leads to school dropouts	50	2.98	1.134	1.285	.216	.337	-.623	.662
Q10 Brick making business has improved socio-economic activities	50	1.98	.958	.918	.476	.337	-.935	.662
Valid N (listwise)	50							

7.5 Correlation coefficient of the parameters.

	pH @ 25°C	*Electrical Conductivity*	*Total alkalinity*	*Nitrate*	*Orthophosphate*	*Calcium*	*Magnesium*	*Iron*	*Turbidity*	*Total hardness*
pH @ 25°C	1									
Electrical Conductivity	-0.95	1.00								
Total alkalinity	-0.89	0.99	1.00							
Nitrate	0.86	-0.96	-0.99	1.00						
Orthophosphate	-0.58	0.74	0.76	-0.70	1.00					
Calcium	-0.97	1.00	0.97	-0.94	0.73	1.00				
Magnesium	-0.89	0.98	1.00	-0.99	0.74	0.97	1.00			
Iron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00		
Turbidity	-0.72	0.48	0.33	-0.27	0.02	0.54	0.33	0.00	1.00	
Total hardness	-0.94	1.00	0.99	-0.97	0.75	0.99	0.99	0.00	0.45	1.00

7.6 Proof reading confirmation

Mrs. Chisha Mutengo, Business Administration BBA University of Sunderland, Diploma in Proof Reading and Copy-Editing Level 4 The Blackford Centre, Communication And Interpersonal Skills At Work Certificate University Of Leeds And Institute of Coding.

P.O Box 6348 Ausspannplatz Tel: 081 6903 705 Email: cmmutengo@gmail.com

01st November 2021

To Whom It May Concern

Re' Editor's Report

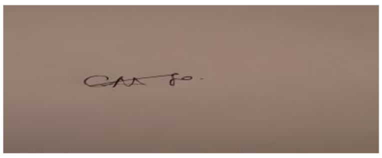
I had an opportunity to Edit and Proofread Rabelani Mabogo's thesis for a Degree in Master's in Environmental Science at the University of South Africa. In accordance with the linguistic components and features:

- Subjects and verbs,
- Rephrasing, making sentences shorter, suggested words with the same meaning
- Punctuation,
- Consistency in the use of words and capitalization

In my edit, I set the computer English Language UK and not USA. I utilised track changes to enable the student/supervisor to either accept or decline the changes where appropriate.

For additional questions and clarity, do not hesitate to contact me on **Telephone: +264 81 6903 705** and on email: **cmmutengo@gmail.com**

Yours Sincerely



Mrs. C. Mutengo

Proofreader and Editor

7.7 Turn-it-in summary

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