HARNESSING ARCHITECTURAL STRATEGIES FOR SUSTAINABLE WASTE MANAGEMENT IN THE DESIGN OF A MODEL DAIRY FARM KADUNA, NIGERIA

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BY

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DECLARATION

I declare that this dissertation entitled "HARNESSING ARCHITECTURAL STRATEGIES FOR SUSTAINABLE WASTE MANAGEMENT IN THE DESIGN OF A MODEL DAIRY FARM KADUNA, NIGERIA''has been carried out by me in the Department of Architecture under the supervision of Dr. A.L. Batagarawa and Arc. M.H. Mukhtar. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at this or any other institution.

Al'Ameen Bambale Ibraheem

_____ _____

Name of Student Signature Date

CERTIFICATION

This dissertation entitled "HARNESSING ARCHITECTURAL STRATEGIES FOR SUSTAINABLE WASTE MANAGEMENT IN THE DESIGN OF A MODEL DAIRY FARM KADUNA, NIGERIA'' by AL'AMEEN BAMBALE IBRAHEEMmeets the regulations governing the award of the degree of Master of Science of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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ABSTRACT

The existing designs of dairy farms have inadequately capture aspects of wholesome waste management in spatial design of process and elements of farmstead facilities designs. The effect of which may lead to cattle health and productivity impairment, negative environmental impact and impaired farm functionality. However, this research aim to assess existing design measures and considerations with regards to their effectiveness in addressing waste management issues on dairy farms in northern Nigeria with the view to develop a design framework for enhancing sustainable waste management in dairy farms designs. As literature reveals that neither agricultural engineers nor veterinarians are equipped enough with sufficient requisite in design understanding to produce a dairy farm design that achieves nexus between infrastructural requirement of cattle breeding, cattle health and welfare with sustainable development ideals: design remains an architects' forte. Using qualitative research design and case study strategy, Nagari Integrated Dairies Ltd, Keffi; Niyya Farms Kaduna, and Lamda Farms, Kadunawere selected through purposive sampling to serve as case studies. Data gathered from the cases covered site planning considerations for waste management, facilities design considerations and design measures and considerations for waste handling as independent variables using observation as gathering technique. Data were assessed using a qualitative scale factor of good, fair and poor. Analytic induction of template analysis was used to analyse assessed data according to the design considerations implemented through variables and strategies which is portrayed using narrative analysis. Looking at the specific strategies, the result showed the need for waste treatment facility, considerations for integrated drainages/rainwater management at design stage, enhanced accessibility around and within farm facilities as the

most crucial design needs. The need for a spatial design of farm from the site layout to the spatial design of unit facilities and the use of enveloping design elements on facilities were established. Finally, the crucial need for zoning facilities based on similar waste generation and the use of vegetation around farm premises were also established. This could guide architects designing dairy farms achieve an effective process through design for wholesome waste management on dairy farms using the design framework developed by the research.

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CHAPTER ONE

1.0 INTRODUCTION

This chapter establishes the background of study, presents the problem statement which usesEllis and Levy (2008) Template for Crafting a Problem Statement (what: who; how, where and when: who; why: who) as a guide. It states the aim of the research and enumerates objectives through which the aim is achieved. The chapter also justifies the problems the research sets out to address and give motivations behind the research as an endeavour. Lastly, the chapter presents a highlight of the study style adopted and gives the structure of the entire work.

1.1 Background to the Study

"Agriculture remains the key driving force for economic growth in most African countries" (Köster and Wolff, 2012). According to Onwualu (2012), agriculture is one of the dominant sectors in Nigeria, as the country is blessed with a favourable climatic condition, richness of soil types and abundant water resources. The high population density provide great potentials for farming in Nigeria.

Dairy farming is anagricultural livestock typology with two main parts: the production of raw milk from dairy livestock on one hand and the processing and distribution of milk products on the other (Russell, 1985; Igwe, 2002 *in* Osotimehin,Tijani and Olukomogbon, 2006).Dairy products provide the most important nutritional requirements for human body building as well as tissues repairs (Osotimehin *et al.*, 2006). However, the dairy sector in Nigeria has been a sleeping giant (Köster and Wolff, 2012).Over the years, Nigerian governments have instituted different motivating policies in terms of import licensing, import prohibition, import tariffs and foreign exchange control on milk products to

encourage dairy farming. Regardless Nigeria meets less than 50% of its domestic need for dairy products making the country the largest importer of dairy products in West Africa, and the import have been rising steadily in recent years (Akinyosoye, 2005).

Unwholesome waste management on dairy farms leads to the breeding of multifactorial disease that affects the health and welfare of dairy cattle and thereby milk yield (Noordhuizen and Cannas, 2009). According to Tongel and Broucek (2010), inefficiency inwaste management on dairy farms result in environmental hygiene concerns which could manifest as lameness and mastitis that affects cattle legs by chronic foot legions and inflammation of udders respectively; these causes pain on the cattle and thereby affects milk productivity and reproduction. Lameness in dairy cow is a hoof/foot rot health condition causing digital dermatitis (hairy heel warts) caused by infectious agents such as Fusobacterium necrophorus and Bacteroides melaninogenicus from decomposed wet environment of a dairy cow which results in higher production losses, lower fertility, and greater culling rates (Garcia, 2010; Hamilton,Moore, Esau, Haupstein, Anderson, Skerritt, and Norris, 2010; Cook, 2004).Mastitis is a bacterial infection affecting the mammary udder of a dairy cow. It is associated with impairment of welfare due to the pain, it is the most costly endemic disease in dairy herds as it transpire into economic loss components in terms of loss in milk production, treatment costs, extra labor and premature culling of chronically infected cows (Hogan and Smith, 2003; Huirne *et al.*, 2002 *in* Noordhuizen and Cannas, 2009).A study by Junaidu, Salihu, Tambuwal, Magaji and Jaafaru(2011) shows that mastitis is a common problem among cattle on dairy farms in Nigeria with about Fifty two (52%) occurrence per anum, while lameness prevalence is at the rate of around (58%) per anum. A study shows that lameness and mastitiscould affects milk yield by decreasing

it to 7liters per day from 23liter per day (Okaiyeto,Ernest, Danbirini and Kudi, 2012; Tongel and Broucek, 2010).

The high quantity of waste from dairy farms raise the level of pollutants that creates major environmental problems (Ogundele and Jegede, 2011; Pretty, 2007). According to Loehr (1984), by cumulative average, a cow is responsible for the production of 14 and 18 tonnes per year of manure and urine respectively. An idea about quantity of wastewater produced from a typical dairy farm is shown in a report by New South Wales Dairy Effluent Subcommittee of 1999. It shows that a typical ranges in water use per cows on dairy farms is reported as 11 to 56 L day^{-1} per cow. While Rogers and Alexander (2000) reports that the water use isat a range of 4 to 138 L day^{-1} per cow (Birchall, Dillon and Wrigley, 2008).Manure is the major source of odour and other greenhouse gases like ammonia (NH3), carbon dioxide (CO_2), hydrogen sulphide (H_2S), methane (CH_4) and nitrous oxide (N_2O) on dairy farms (Battye *et al.*, 1994 *in* Topper, Brandt, Adviento-Borbe, Lascano, Heinrichs and Wheeler, 2008). In a study by Jacobson, Bicudo, Schmidt, Wood-Gay, Gates and Hoff (2003), dairy farms has odour emitting potential of about 1.3 – 3.0 OU m^{-3} against poultry which emits 0.3 – 3.5 OU m^{-3}.While as for greenhouse gas emissions, ammonia concentrations in livestock section of a dairy farm range from 5 – 15g NH_3 m^{-2} day^{-1} depending on the flooring (Jacobson *et al.*, 2003), nitrous oxide is within the range of 0.4 – 26g N_2O AU^{-1} day^{-1} depending on waste management system adopted (Esfandiari, Khosrokhavar, Sekhavat, 2011). While Hydrogen sulphide is at around 0.09 – 0.25g H_2S m^{-2} day^{-1} and methane goes up to about 70kg CH_4 $animal^{-1}$ $year^{-1}$(Schiefler, 2013).

Animal wastes is probably the largest sectoral source of water pollution, contributing to eutrophication, “dead” zones in coastal areas, degradation of coral reefs, human health

problems, emergence of antibiotic resistance and many others. These pollutants indicates freshwater shortage, scarcity and depletion, with 64 percent of the world's population expected to live in water-stressed basins by 2025 (Hubbard,Lowrance, Vellidis and Davis-Carter,1991; Food and Agriculture Organization of the United Nations, 2006; FitzGibbon, Kato, Summers, Vargas, Simons, Zhang and Menke, 2005; Government of Western Australia Department of Water, 2012).

Waste from livestock are responsible for an estimated 55 percent of erosion and sediment around the world (Van Breemen *et al.*, 1982; Speirs and Frost, 1987; Roelofs *et al.*, 1985; Speirs and Frost, 1987*in* Jacobson *et al.*, 2003; Food and Agriculture Organization of the United Nations, 2006). Waste from livestock play an important role in the current biodiversity crisis, as they contribute directly or indirectly to drivers of biodiversity loss, at the local and global level. It is estimated that a loss of species is running at 50 to 500 times higher than background rates found in the fossil record; these are linked to changes in habitat, climate change, invasive alien species, overexploitation and pollution (El-Haggar 2007; Food and Agriculture Organization of the United Nations, 2006).

Greenhouse gas (GHG) emissions on dairy farms and its climate change concern have received little attention until recently as it becomes a priority for most sectors of the economy: industrial agriculture inclusive (Birchall *et al.*, 2008). There are numerous sources of odour with pollution potentials on dairy farms. These odours are a composite of over 170 trace compounds, including greenhouse gases (Birchall *et al.*, 2008: Herbut and Angrecka, 2014: Zhao, Combs, Rausch, Manuzon, Brugger, Arnold and Imerman, 2008). Common air emission sources on dairy farms are mainly animal housing/manure harbouring areas, feeds processing and waste handling areas (The State of Victoria, 2010;

Jacobson*et al.,* 2003). Reidhead (2010) found that each cow on average is responsible for 1,500 lbs of GHG per year or about 1,395 pounds CO_2 equivalent per year. Also, dairy farms emits 37 percent of anthropogenic methane (with 23 times the global warming potential (GWP) of CO_2). It emits 65 percent of anthropogenic nitrous oxide (with 296 times the GWP of CO_2), the great majority from manure, and also responsible for almost two-thirds (64 percent) of anthropogenic ammonia emissions, which contribute significantly to acid rain and acidification of ecosystems (Calker,Rudi, Alfons and Mauser, 2005; Sleinfield, Berber and Hillary, 2006; Food and Agriculture Organization of the United Nations, 2006).

The challenges of waste management on dairy farms emanates from inefficient design approach, inadequate infrastructure and management systems,inadequate use of modern technology and construction of standard cattle and milking facilities (Adeneye, 1991 *as cit.* Osotimehin *et al.,* 2006; Ugwu, 2010). In a study by Ugwu (2010), waste management on dairy farms in Nigeria are in part responsible for low milk production and environmental impact.

1.2 Problem Statement

Most architectural designs of dairy farms do not adequately capture the aspect of proper waste management (Cook, 2002). The situation of elusive waste management on dairy farms is affirmed pointing at design flaws in achieving good spatial design and standard farmstead facilities (Shete and Shinkar, 2013; Osotimehin *et al.,* 2006; Abubakar and Ismail, 2012; Ogundele and Jegede, 2011; Cook, 2002): dairy farms in Nigeria are no exception to these inadequacies (Junaidu *et al.*,2011; Ugwu, 2010). Waste (amount of manure and urine) in cattle environment forms a predictor index for cattle health and

welfare impairment throughbreeding of harmful pathogens responsible for environmental mastitis (inflammation of udders) and lameness (chronic foot legions): aside the immense pain endured by the animals, these health impairment also reduce milk yield (Noordhuizen and Cannas, 2009; Tongel and Broucek, 2010; Chaiudhari and Dhoble, 2010; Abubakar and Ismail, 2012). More so, environmental degradation also arise resulting from pollution andgreenhouse gas emissions caused by unwholesome waste management from dairy farms through water, air and soil pollution and also decrease in biodiversity, climate change and increased global warming potentials(Food and Agricultural Organisation of the United Nations, 2006; Sorathiya,Fulsoundar, Tyagi, Patel and Singh,2014; Reidhead, 2010; Sleinfield *et al.*,2006; Abubakar and Ismail, 2012; El-Haggar, 2007). While there could be a number of factors at play and different stakeholders involved in addressing issues of waste management on dairy farms, Cook and Nordlund (2004) and Cook (2002) recommends that more research is needed on the designs of dairy farms to ascertain implications and consequences of design decisions on waste management process, on-farm activities and animal welfare. With the need for more dairy farms to produce more dairy products on the rise; the animal welfare and productivity, environmental degradation impact from flaws in existing designs of dairy farms in proper waste management still prevalent on dairy farms; and studies recommending the need for more research on dairy farm designs in addressing waste management issues, this research look into dairy farm designs with the view on how architectural design should proffer primary solution through spatial organization and standards in architectural design modalities to achieve a dairy farm design that offers a wholesome process for waste management.

1.3 Justification

Nigeria is a potential market for 1.3 million tons per annum of milk valued at about $3 billion (USDA Foreign Agricultural Service, 2007). Biu (2011) established that there is a tremendous demand for dairy products in the Nigerian Market, mostly in urban areas. While Osotimehin *et al.* (2006) found that Nigeria has the potential of being a major milk producer in Africa.According to Ugwu (2010), the climatic condition and topographical features of most places in Nigeria are favorable for small, medium and large-scale dairy farming.

Waste management systems affects animal operations economically and also environmentally (Sorathiya *et al.,* 2014). According to Abubakar and Ismail (2012), theinadequacy of waste management techniques on dairy farms cause adverse environmental problems and other health problems on cattle through breeding pathogens. According to Chaiudhari and Dhoble (2010) and Shete and Shinkar (2013), ineffective waste management on dairy farms is a consequence of poor farm design, operation and waste treatment system.

Environmental protection is seen as the major problem facing the world today (El-Haggar, 2007). The Kyoto protocol has gain more political recognizance in terms of environmental safety and climate change thereby reiterating the need for a more sustainable approach to human activities (Saunders and Barber, 2008). Livestock agriculture is in spotlight of need to minimize their waste impact on the environment through pollution control and reduction in greenhouse gas emissions from agricultural sector (FitzGibbon *et al.,* 2005; Reidhead, 2010; Herbut and Angrecka, 2014; Zhao*et al.,* 2008). Global production of milk is projected to grow from 580 to 1,043 million tonnes from 1999/01 to 2050, this impliesthat

the environmental impact per unit of livestock production must be cut by half, just to avoid increasing the level of damage beyond its present level (Food and Agriculture Organization of the United Nations, 2006).

It is necessary for any establishment to treat its waste so that it complies with environmental protection regulations. The impact of waste disposal on the environment is significant since it contaminate air, soil, and water (El-Haggar, 2007). According to Ngumah *et al.* (2013), records show that Nigeria ranks number 8 in the world in greenhouse gasses emission (13% of world emission). About 28.8% of these emissions comes from untreated organic wastes, such as those from a dairy farm. Abubakar and Ismail (2012) affirms that there is pressure in many parts of the world to ascertain how livestock waste should be handled in order to curtail its impacts.

Birchall *et al.* (2008) found that under some state acts, designers are required to consider safety in their designs. They are tasked with ensuring a design that practically eliminate or reduce any adverse effect on the users and the environment. Also according to Horn (1998), designers have an overriding responsibility to protect local and global planetary systems through designs that are oriented in protecting and eliminating all pollution activities. On that note, Fatah (2012) propagates an eco-design approach which considers designing built environment with special consideration for the impact of the design and the buildings on the planet Earth from an ecological standpoint; environmental friendly architecture in both design process as well as the structure that results from the design process.

1.4 Aim and Objectives

The aim of the research is to assess existing design measures and considerations with regards to their effectiveness in addressing waste management issues on dairy farms in northern Nigeria with the view to develop a design framework for enhancing sustainable waste management in Nigerian dairy farms.

The research thus intends to achieve the aim through the following objectives:

I. To investigate design strategies for waste management on dairy farms Nigeria.

II. To determinethe impacts of such design strategies for waste management on dairy farming in Nigeria.

III. To determine the effectiveness of a design framework for enhancing sustainable waste management for large scale dairy farms design.

IV. To bring to the fore the applicability of this framework through the proposed design of a model dairy farm in Kaduna.

1.5 Research Questions

The study intends to answer the following research questions:

I. What are the design strategies for waste management used on dairy farms in northern Nigeria?

II. To what extent are design strategies effective in enhancing sustainable waste management on dairy farms in northern Nigeria?

III. How effective could a design framework be in enhancing sustainable waste management on large scale dairy farms?

IV. How best can design strategies be incorporated at design stage to enhance sustainable waste management on dairy farms?

1.6 Motivation

Dairy farms in Nigeria mostly use breeds of cattle from the temperate regions owing to the fact that indigenous breeds of the tropics are generally characterized by low genetic potential for milk production. Also, the climatic difference with credible potentials for leading to diseases and reduced milk production necessitate keen considerations for conducive cattle environment (Ogundipe and Adeoye, 2013). In an interview with Prof. Jerome Gefu, the Executive Director of National Animal Production Research Institute (NAPRI), the acute difference in milk yield between the indigenous breeds and the exotic breeds was explained. An example is the institutes' tregian exotic breed that yield up to 35liters of milk per day against a bunaji indigenous that yields around 5liters of milk per day. However, the major challenge for the exotic breeds he noted is the need of the exotic breed for better management, need for cooler space, good environment and feeding (Sa'idu, 2014). While Junaidu *et al.* (2011) submits that the economic implications of environmentally caused health and welfare issues of dairy farms are as important as they are so far not properly addressed on Nigerian dairy farms.

Architectural professionals have to accept the fact that as a society's economic status improves, its demand for architectural resources increases (Kim and Rigdon, 1998). Looking at the goals of sustainable designs, architectural solutions that guarantee well-being and coexistence is needed. Thus Fatah (2012) opines that architects and building designers can play a major role in promoting sustainability and ethical responsibility for the

future generations and bio-system through responsible approach of design towards nature and earth, and it is the participation of architecture in to the living system through its understanding and integrated design approach.

Flaws in design features can lead to welfare and health outcomes on dairy cattle like traumatic injuries, sore feet, environmental mastitis and lameness (Dairy Farmers of Canada, 2009: Birchall *et al.,* 2008). As a result of good environment, dairy cows can maintain good productivity throughout the year which implies more farm profitability (Gay, 2009). While Samer (2010) highlights that design flaws in housing designs in dairy farms increases heat stress which dramatically decreases milk yield and thereby leads to economic deficiency of the farm. Improving the environment in which dairy cattle are reared is of major concern in terms of housing, providing comfort and other environmental factors, stating that without improving the environment, low animal productivity is inevitable (Ikhatua, 2000; Prabu, 2013).

Respect for environment and sustainable development is part of the agenda of President Muhammadu Buhari administration (thenationonlineng.net, 2015). In a UN General Assembly address of 2015, President Muhammadu Buhari reaffirms Nigeria's strong commitment which reflects African consensus to the adoption of a legally binding universal agreement to mitigate climate change through contributing in reducing greenhouse gas emissions worldwide and that Nigeria will continue to champion the core principles and goals of the new sustainable development agenda in hopes that the next conference of parties will eventually become a global milestone to combat and cushion the dire impacts of climate change (IBTimes Staff Reporter UK, 2015). To this end,

developments in Nigeria need to depicts political will for championing sustainable development ideals, a good example been the waste management issues on dairy farms.

According to Jacobson *et al.* (2003), unfortunately design of waste management process and implied environmental conditions regarding dairy farms are either not well understood or documented. While veterinarians don't have the necessary skills for design and construction of dairy farmstead; they are more into the health, behaviour and welfare of the cattle. Agricultural engineers are mainly concerned with cost and other non-health related issues of dairy farmstead (Cook, 2002), proper dairy farms design thus falls on the architect whose design integrates all stakeholders and their respective peculiarities in coming up with a viable design. This research thus intends to find the actual state of dairy farm designs through the strategies used as means for waste management under the spectrum of architectural designs.

1.7 Scope

Looking at the nature of the research, this section sets a purview of consideration for the work. The concept of the work however is a qualitative study of the architectural strategies for waste management used on case farms within northern Nigeria region within the time range of the research. The choice of the geographical location to be covered is strengthened by RIM (1992) *in* Blench (1999), stating that most states in northern Nigeria are suitable for dairy farming, also a wide conception that agriculture is the most dominant economic drive of northern Nigeria owing to the availability of favourable land and climatic conditions for agriculture. Therefore, the research chose Nassarawa and Kaduna States as representative study areas.

However, the research limits the nature of waste to be considered using the Federal Government of Nigeria's efforts to control and manage wastes from dairy and animal facilities in the country through enacting laws in section 20 of the 1999 Constitution as amended proffer the legal framework for waste management in Nigeria (Dixon, 2012; Ijaiya, 2013), the research thereby considers Regulation 2.E (Confined Livestock Feeding Industry) and Regulation 2.G (Dairy Industry) that names the waste of these industries as Biological Oxygen Demand (manure, effluent, waste water and wash water) and greenhouse gases emissions among others. To that end, the research relies on Cook and Nordlund (2004) and Cook (2002) recommendations that design is the key to waste management issues on dairy farms. And also,Abubakar and Ismail (2012) and Sorathiya*et al.*(2014) to limit points of emphasis to how architectural strategies in dairy farms is used to enhance waste management on dairy farms and curtail its health and environmental degradation impacts.

CHAPTER TWO

2.0 LITERATURE REVIEW

This chapter review and discuses relevant literature to the research purview through mapping of sections, sequentially. It serve as roots through which the data to be collected on the field emanates. It establishes base for the research framework by building up a sequential flow of sections discussing what dairy farm as a building typology is all about, to the nature and quantity of waste generated from the dairy farm reiterating significance warranting the need for waste management up to the general implications of these wastes and then the design strategies to be adopted in enhancing waste management in its different ramifications on dairy farms giving measures and considerations that suite principles of sustainable waste management on dairy farms.

2.1 Dairy Farm

Dairy farm is a complex of facilities for the production and processing of milk products. It is thus made of cattle environment; housing, cattle yards and laneways, and pastures; manure storage and handling facilities which deals with manure, effluent and wastewater; feed centre for processing and bulk storage of cattle rations; animal health section which comprise of vaccination, isolation unit, observation area, treatment area and storage space for veterinary cattle treatment; milk house (milk centre) where cows are milked and the first bulk storage for freshly harvested milk; processing plant where harvested milk is processed into finished dairy product; and other farm ancillaries like on and off-loading bay, dips and crushes (Hamilton *et al.,* 2010).

In a report, Köster and Wolff(2012) characterizes large scale dairy farm as a complex having large herds (more than 50 mature cows) which gives a sense of measure for the quantity of waste produced on the farm; generally zero grazing which gives the criteria for confinement of the cattle in a space where the waste produced have a bearing on the cattle; heavy/very heavy mechanization which gives an idea for the measure of how advanced the farm is, and gives significance of machinery as it affects waste management; disease problems and heat stress which gives a base for crowd of dairy cattle in a confined space with generated waste; artificial Insemination (AI) as the common mode of insemination which simply adds to the advancement of the dairy farm; processing facilities to enable direct sales to the customers which give a base for generating other waste apart from livestock waste and also requiring some management considerations.

Milk on dairy farm is produced by the cattle in the cattle environment (livestock section of the farm) while processing safe, wholesome and high quality dairy products is done in varieties like consumer milk, butter, cheese, yogurt, condensed milk, dried milk (milk powder), and ice cream, using processes such as chilling, pasteurization, and homogenization: this process starts from the milk centre up to processing plant where dairy products are produced (Sigurdson and Cords, 2014: Singh, Singh and Imam, 2014).

2.2 Sustainable Waste Management on Dairy Farms

Sustainable waste management on dairy farms strives to achieve a farming practice that protects and enhances the natural environment and animal welfare while simultaneously ensuring profitability (Bylin, Misra, Murch and Rigterink, 2004: Menalled,Bass, Buschena, Cash, Malone, Maxwell and Weaver, 2008). The pollution effect of waste from a dairy farm has prompt many dairy farms to heed more considerations for managing waste on

their respective farms (Esfandiari *et al.,* 2011). Design and planning of dairy farm facilities is a sophisticated task. It requires the understanding and implementation of a multitude of procedures and processes (Samer,Hatem, Grimm, Doluschitz and Jungbluth, 2012).

2.3 Principles of Sustainable Waste Management on Dairy Farms

Wholesome waste management lends more credence to global sustainability (El-Haggar, 2007). According to Pretty (2007), concerns about sustainability covers agricultural practices that:

i. Do not have much adverse effects on the environment
ii. Are accessible to and effective for farmers, and
iii. Lead to both improvements in food productivity and have positive side effects on environmental goods and services.

According to Agriculture and Resource Management Council of Australia and New Zealand (1999), a dairy farm design should have an objective of minimizing the environmental impacts of its activities through the following guiding principles:

i. Avoidance or elimination of excessive waste generation through better planning
ii. Optimization of waste management processes
iii. Effective and feasible recycling and reuse of effluent
iv. Disposal, where it is not practicable, in a manner that will not cause short or long term adverse environmental impact.

While according to Rogers (2008) measures forminimizing negative impacts of dairy farm waste include:

i. Site selection and design

ii. Careful planning and siting of the dairy farm facilities in terms of the farm layout: separation distances, zoning and orientation

iii. The use of trees and windbreaks to serve as barriers by wind could help promote vertical air mixing and dilution of odours.

iv. Good management of all the facilities i.e adequate infrastructural requisite for best environmental management practice to be applied in the design of facilities, waste management systems, herd management and general farm management.

Waste management system for a modern dairy farm should be capable of controlling waste in solid, semi-liquid, liquid and gaseous emissions forms from all farm facilities(Barker, 1996). Furthermore, it should as well have a possible consideration for sustainable reuse of these waste (Rogers, 2008). A new hierarchy for sustainable waste management generally as proffered by El-Haggar (2007) is one which must starts from reduction at source, efficient handling process and sustainable treatment in conservation of natural resources to approach full utilization of resources.

2.4 Hierarchy for Waste Management on Dairy Farms

Based on El-Haggar (2007)hierarchy for sustainable waste management,the design strategies will thus be discussed through:

i. Considerations for reducing waste generation

ii. Considerations for efficient waste handling process

iii. Measures for sustainable waste treatment.

2.4.1 Considerations for Reducing Waste Generation

Reducing waste generation on dairy farms through design is viewed through the following considerations:

i. Use of waste reduction measures (Brião and Granhen-Tavares, 2007; Ndegwa and Harrison, 2002)

ii. Achieving dry indoors within the farm buildings (Jacobson *et al.*,2003; Rong,Liu, Zong and Zhang, 2014; Carlsson, 2005; Ludington, 2004; Gay, 2009)

iii. Flooring design within the farm buildings (Dairy Farmers of Canada, 2009; Jacobson *et al.*,2003; Bickert, Holmes, Janni, Kammel, Stowell and Zulovich, 2000)

2.4.1.1 Use of Waste Reduction Measures

Planning and designing dairy farms to operate in a mechanised process makes for efficient use of resources. According to Brião and Granhen-Tavares (2007), installation of C.I.P (Clean-in-Place) system (a technological system of automatic washing and sanitisation of milk processing machineries) in dairy farm operations makes for an efficient use of water and consequently the amount of wastewater to be generated from farm facilities and its eventual impact on the environment, as it aids the reuse and recycling of water which also reduce the volumetric co-efficiency of water used.

Manure treatment technologies can be very effective at odour control (Ndegwa and Harrison, 2002). Control technologies used to reduce the production or generation of odorous gases include the use of a suitable manure treatment technologies. Other means of reducing waste generation however are diet manipulation, chemical or biological additives in waste treatment. While according to Birchall *et al.* (2008), solid liquid separator (a machine used in segregating between the liquid and solid contents of effluent before final treatment) could be used as a system that captures most of the precursors to gaseous

emissions generation (carbon compounds, proteins and nutrients) as they are contained in the finer particle fraction.

2.4.1.2 Achieving Dry Indoors

Aside the physiological need for thermal comfort by the dairy cattle, dry indoors according to Jacobson *et al.* (2003) ensure substantial reduction in emissions generation from dairy farm facilities. However, this could be achieved through effective ventilation of the facilities' interior (Jacobson *et al.,* 2003).

To achieve proper ventilation on dairy farm buildings generally, Dairy Farmers of Canada (2009) opines that measures to increase air exchange should be ensured. This could be done through walls and roof designs, and also through proper orientation of farm facilities (Jacobson *et al.,* 2003; Rong *et al.,*2014; Carlsson, 2005).

After analysing positive, negative and neutral pressure ventilation systems for animal housing generally, Carlsson (2005) recommends that a positive pressure system which have fans that blow air into the building, then a positive pressure is created in the building and air will exit the building through exhaust openings has a good performance rating, mostly for the tropical climate.

In terms of wall fenestrations design of the barn facilities, Ludington (2004) opined that wall design of dairy farm buildings should bein high-sided and open facilities while also providing sufficient confinement for the cattle. While Gay (2009) said roof should be designed with a peaked ridge with an open ridge sides: this provides a natural outlet for warm and vitiated air that aids better air exchange rate within the farm building. Figure 2.1 illustrates different ridge configurations.And according to Rong *et al.* (2014), orienting

dairy farm facilities should be made such that the barns' wider sides faces east-west while others should retain north-south orientation: this ensures dry indoors and also reduced heat gain respectively.

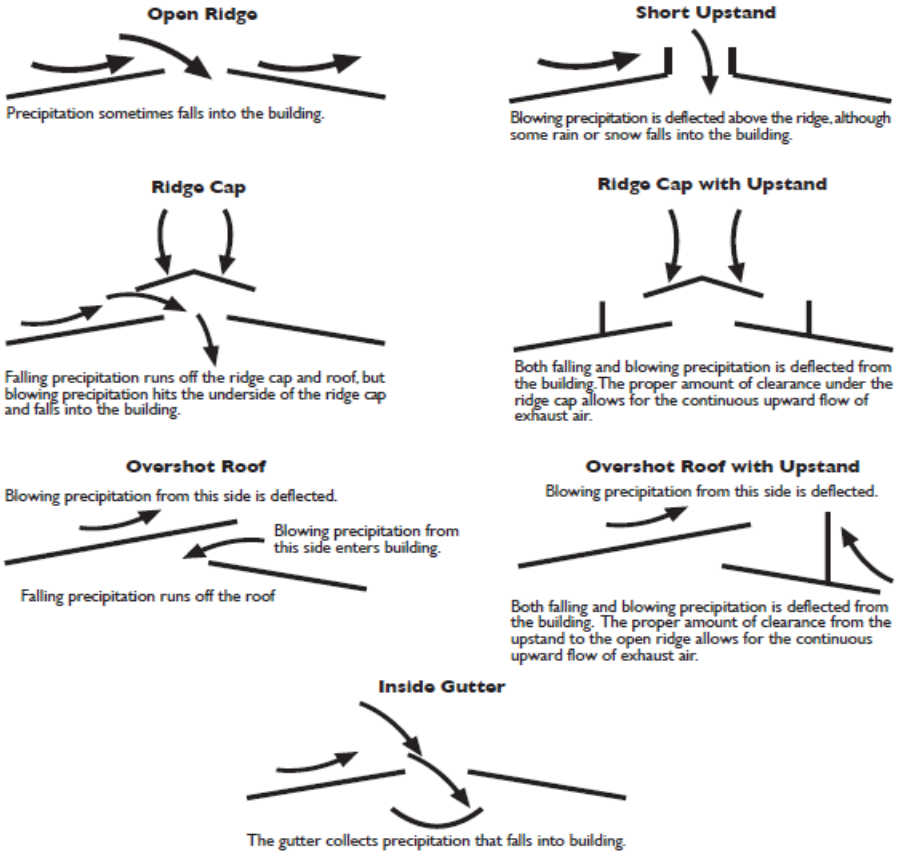


Figure 2.1: Different Roof Designs on Dairy Farms

Source: Gay (2009)

2.4.1.3 Flooring Design

Flooring design in dairy farm buildings should be designed to have a texture/pattern that functions as a base for easy waste evacuation, reduce the emission rate from the on-floor waste, provides a secured footing, reduce chances of injury, slipping or falling and enhance secured movement (Bickert *et al.*, 2000). Floor designed in double slope to a central gutter is found to enhance ease in waste evacuation and reduce emissions rate by around 50%

(Dairy Farmers of Canada, 2009; Jacobson *et al.*, 2003). In a Study by Graves,Georg and Lensink(2014), a flooring system design called dutch-grooved-floor is developed based on cattle welfare, ease in waste evacuation and reduction in emissions to cater for contemporary need of dairy farms design. Plate I shows a depiction of a dutch grooved floor.



Plate I: Dutch Grooved Flooring

Source: Graves et al(2014)

2.4.2 Considering Measures for Frequent Waste Evacuation

The considerations for effective waste evacuation within farm buildings is viewed through the following:

i. Spatial design of barns (Cook and Nordlund, 2004; Graves *et al.*, 2014)
ii. Integrating Waste Collection Infrastructure (Birchall *et al.*,2008; Garcia, Tjardes, Stein, Ullery, Pohl and Schmit,2004; Jacobson *et al.*,2003)
iii. Accessibilitynetwork for waste collection (Jacobson *et al.*,2003; Powell and Lapworth, 2006; Singh *et al.*, 2014)
iv. Zoning and location of farm facilities (Garcia *et al.*,2004; Rogers, 2008)

2.4.2.1 Spatial Design of the Barns

The design of animal facility affect the effective management of waste and have a major impact on gaseous emissions from the facility (Jacobson *et al.,* 2003). Spatial design of dairy farm barns is done base on rows of animal stalls and lying position of the rows in respect to one another: either head-head or tail-tail configurations (Neufert and Neufert, 2012).

A study by Cook and Nordlund (2004) shows that the spatial design of the barn buildings affect the efficiency in ease of waste evacuation from animal buildings, natural measures for waste handling, safe and healthy cattle stocking density, and a measure for curtailing possibility for disease transmission from one cattle to another. Graves *et al.* (2014) however found that a spatial design of a dairy barn with a two-row configurations with tail-tail design and a central alley performs better in terms of ease in waste management and animal welfare.

2.4.2.2 Integrating Waste Collection Infrastructure

Waste collection infrastructure on dairy farm is a system of waste evacuation from dairy farm facilities and the farm premises that include collection and distribution infrastructural network inherent in the farm design (Jacobson *et al.,* 2003; Powers and Borrie, 2013). However, waste management system adopted for any dairy farm not only influences the facilities design, but also affects the total farming operation, it is an integral component of the production system (Bickert*et al.,* 2000).

Within the barns, waste can either be flushed, scraped, or vacuum collected (Burke, 2001: The State of Victoria, 2010). Furthermore, adopting flush and scraping system

concurrently boast waste management in all ramifications, including substantive reduction in gaseous emissions (Lenkaitis, 2012; Hubbard *et al.*,1991). Also, Jacobson *et al.* (2003) found that using gutters and narrow collection channels within dairy farm buildings help reduce emissions from a dairy farm from 30 to 70% as compared to conventional buildings, in a comparative study.

Around the farm premises, however, Bickert *et al.* (2000) opines that runoff management should be given adequate consideration:these management scheme is a two-faced consideration. The first been not allowing clean upslope runoff to flow into a feedlot by using curbs anddiverts,and terraces, divert roof to keep rainwater away from the barns. The second consideration is channelling the polluted runoff to a collection/treatment plant using gutters or pipes.

2.4.2.3 AccessibilityNetwork for Waste Collection

Waste collection network for ease and effective waste evacuation is mostly concerned with adequate design measures complementing frequent waste removal from dairy farm buildings in terms of adequate space size and integrated network for physical movement of cattle and farm workers. This is achieved through an integrated network of alley within barns (Jacobson *et al.,* 2003), races around farm premises (Powell and Lapworth, 2006) and road networks around farm premises (Singh *et al.,* 2014).

2.4.2.4 Zoning and Location of Farm Facilities

In a study by Garcia *et al.* (2004), zoning and locating farm facilities based on the nature of the facility use and waste output is established to be of sufficient importance in making for ease in collecting similar kind of waste using complementary collection and distribution

network. According to Rogers (2008), site terrain is a crucial factor in locating dairy farm facilities, revealing that zoning animal housing facilities, milk related areas, feed mills, waste treatment area and staff amenities (administrative block) should consider topographical elevation in placing waste generating facilities at the lowest elevation and hygienic facilities at highest elevation.

2.4.3 Measures for Sustainable Waste Treatment

The measures for sustainable waste treatment on dairy farms is viewed through the following:

i. Waste treatment facility (Birchall *et al.*,2008)
ii. Use of vegetative barriers and buffer distance (New Zealand Ministry of Primary Industries, 2013; Samer, 2010; Garcia *et al.*,2004)
iii. Installation of bio filters (Garcia *et al.*,2004)

2.4.3.1 Waste Treatment Facility

Sustainable waste treatment is a new term according to El-Haggar (2007) and is defined as the type of treatment or combination of different types of treatments able to recover the raw material in order to conserve the natural resources. Birchall *et al.* (2008) opines that a waste treatment system on dairy farm should have sumps, solid-liquid separator and a treatment facility.

Sumps

Sumps are the first temporary store for liquid waste on dairy farm and in some cases a collection store for rainwater and runoff. These sumps can be small to ensure entrainment of solids or large to serve as a pre-treatment facility and even emergency storage. As sumps

are generally in-ground and can be confined spaces, they need to be designed for secure and safe access. (Birchall *et al.*,2008). Figure 2.2 shows a typical dairy farm sump.

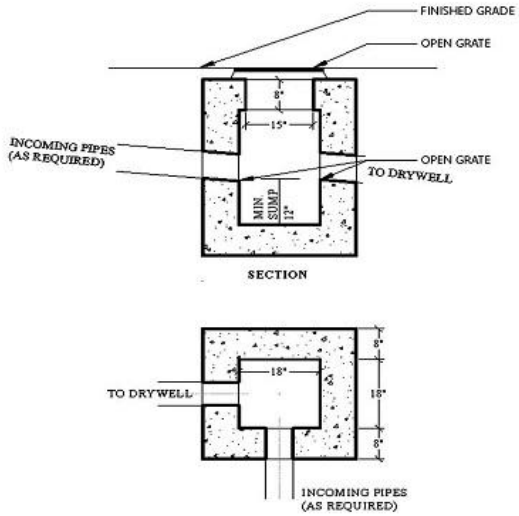


Figure 2.2: Typical Dairy Farm Sump

Source: codes.iccsafe.org (2014)

Solid-Liquid Separation System

Liquid-Solids Separation system is a method currently being used as a manure and effluent handling practice on many dairy farms (Wright-Pierce, 2005). A variety of methods are currently being developed and utilized in order to effectively dewater dairy manure. The goal of the dewatering process is to isolate nutrients in the solid form and separate a nutrient deficient liquid from a solid material. Solid and liquid phases produced during the liquid-solids separation process must still be disposed. Currently, there is no economical method of treating manure so that the treated liquids can be disposed in a watercourse. However, by separating out a nutrient rich solid, the liquid can be spread on fields at higher application rates due to the lower nutrient content. The left over solids can be more easily transported off-site and applied to land elsewhere or treated further to develop a saleable

fertilizer (Wright-Pierce, 2005; Birchall *et al.*,2008). Figure 2.3 shows a typical solid liquid separator.

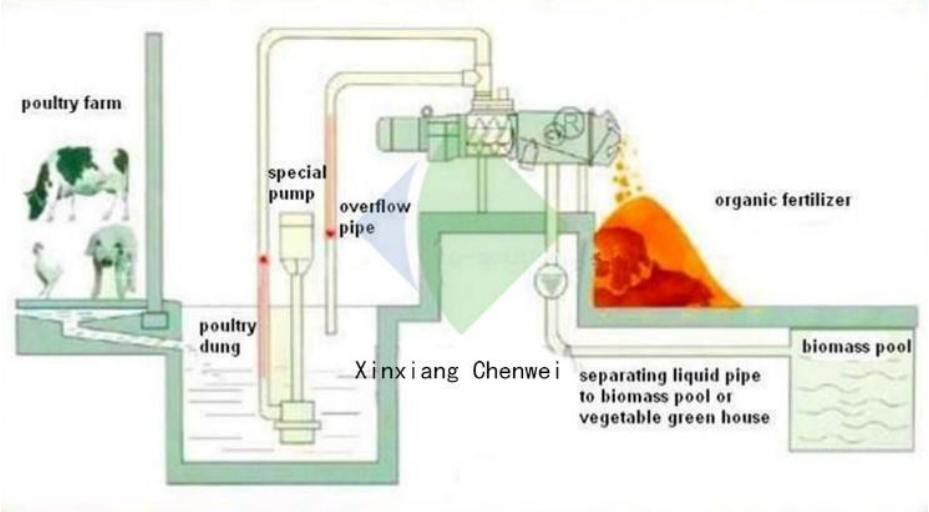


Figure 2.3: Typical Solid-Liquid Separator

Source: alibaba.com(retrieved 7th May 2016)

Storage/Treatment Facility

Aside health and environmental impact necessitating better waste management, Wright-Pierce (2005) opines that dairy farm waste can be seen as commercial fertilizer product. Although, raw dairy farm waste contain high amount of weed seeds, pathogens and air emissions potential, it is seen as a fertilizer product in itself.

In treating the waste, using cost effective technologies produce better quality product. Treated dairy farm waste product could be used for green houses, fruit farms, landscaping works, athletic fields, poop pots (an experimental technology used in planting gardens in green houses made from composted manure), and ash from combusted manure. According to Birchall *et al.* (2008), popular treatment options are:

i. Composting

ii. Wetlands

iii. Anaerobic digestion.

Composting

Composting is the biological aerobic decomposition of organic materials by microorganisms under controlled conditions to a stable product (El-Haggar, 2007; Wright-Pierce, 2005). According to Birchall *et al.* (2008), composting is a manure management system which does not simply consist of placing accumulated manure in a pile and leaving it to rot down. The process relies upon control of temperature, moisture and feedstock and on supplementation of the manure with straw, sawdust or hay to serve as a source of carbon. It is the breakdown of relatively dry manure by microorganisms and fungi under aerobic, moist conditions. The naturally elevated temperatures foster microbial growth, kill weed seeds, encourage pathogen die off, kill helminths and cysts, and reduce generation of noxious gases. During composting, the readily biodegradable component of the waste is oxidised (converted to carbon dioxide, water and heat), leaving a virtually odourless material which can be safely used as plant fertilizer (humus). And could be used by residential users, topsoil manufacturers, landscapers, and others. Although, the major risk of this method is odour generation during the composting process and the emissions of greenhouse gasses (Wright-Pierce, 2005; Ndegwa and Harrison, 2002).

Composting yields product that is more cost effective and environmentally friendly than some other management options, including storage and landfill. Stable compost does not provide a medium for the breeding of flies. Well managed compost generates less greenhouse gas than stockpiled manure. The result is a higher-value that has a higher nutrient density and availability than raw manure, thereby improving the cost-effectiveness

of reuse product suitable for use in high-return industries such as horticulture and urban landscaping (Birchall *et al.*, 2008).

Furthermore, Birchall *et al.* (2008), Wright-Pierce (2005) and Kansas Department of Health& Environment (2003) discuss different composting methods. Among the methods, windrow system has little process control and a long stabilization period, and is more common. The totally enclosed composting reactor used is high in capital cost, complex design and high level of process control, but it is more efficient. While Bin Composting Systems use a bin turner to aerate the composting material and move the material down the bin. In addition, the material can be aerated from below using fans. The advantage to bin systems is that they generally require a smaller footprint and can increase the rate of composting. In addition, since the process is enclosed in a building, the odorous air can be collected and treated to reduce odour emissions from the facility. However, Birchall *et al.* (2008) opine that if insufficient oxygen is supplied, anaerobic conditions will result, reducing quality, producing noxious gases and generating more greenhouse gases. The aim of composting should be to yield consistent product quality. To achieve this, the process must be monitored. In particular, the finished product should be analysed for pH, moisture and nitrogen, especially if it is to be sold.

Regardless of the composting method, Wright-Pierce (2005) reports that all the composting systems have basic features in common:

i. A mixing area where the manure is combined with the woodchips/leaves or other amendment;
ii. A composting area where the mixed feed decomposes into a compost product;
iii. An odour control system to treat the exhaust from the system if needed;

iv. A curing area to allow the compost to cure to a finished product;

v. A storage area to stockpile finished compost produced during the off-season (e.g. during the winter when demand for compost is low); and

vi. A screening area where the product is screened to remove large size pieces such as partially decomposed woodchips. (These woodchips can be recycled back into the basic feed mix.)

Of note and importance is the site selected for a livestock composting facility on dairy farm. Kansas Department of Health& Environment (2003) proffer consideration for site selection to include view away from the general public, have easy all weather access, have enough storage area for the co-composting material, and be located in an area which will be protective of ground and surface waters, It should have good drainage, limit environmental risks, provide for all weather operation, and provide an adequate area for all operations of the composting facility. However, Wright-Pierce (2005) found that composting is the best manure treatment that aids water protection as compost helps hold nutrients and stabilize the product when applied to soil rather than allowing them to wash into the surface water.

Wetlands

Wetland is an expanse of land used to capture farm runoff, and in some cases treat dairy effluent and wastewater. There are two different types of wetlands natural wetland and constructed wetland (Birchall *et al.,* 2008).

Wetlands provide an inexpensive and easily operated means of removing organic matter, suspended solids, nutrients and micro-organisms from agricultural wastewater, especially the constructed wetlands (Van Deun and Van Dyck, 2010). Birchall *et al.* (2008) opines

that the associated changes in nutrient, salt and water balances from wetland treatment are rarely positive. It goes along with manure stockpile method for manure handling.

Anaerobic

Anaerobic storage/treatment is a mechanical-biological treatment plant that has a three-stage process—hydrolysis, fermentation (or acidogenesis) and methane formation (or methanogenesis)—with different groups of bacteria involved in each (Hellweg, Doka, Finnveden and Hungerbühler,2005). E Source Companies LLC. (2010) opines that anaerobic treatment is a solution to managing waste from cows with potentials to reducing energy costs. In addition to providing a treatment route for manure, it's a good opportunity for sustainable waste treatment that aids odour control on farm, and reduce the overall environmental impact of the waste, it also has fertilizer as an end product, and biogas. Looking at the energy analysis by Torquati, Venanzi, Ciani, Diotallevi and Tamburi(2014), estimates show that dairy anaerobic digesters could produce between 4 and 5 kWh per cow, per day. But in order to achieve the benefits of anaerobic digestion, Burke (2001) opines that the treatment facility must be integrated into the dairy operation.

Anaerobic digesters provides a variety of benefits. The environmental benefits include:

i. Odours are significantly reduced or eliminated.
ii. Flies are substantially reduced.
iii. A relatively clean liquid for flushing and irrigation can be produced.
iv. Pathogens are substantially reduced in the liquid and solid products.
v. Greenhouse gas emissions are reduced.
vi. And finally, nonpoint source pollution is substantially reduced.

However, Wright-Pierce (2005) found that anaerobic digestion does not convert nutrients into a product which can be transferred to another sector for distribution. Another consideration however is that using anaerobic digesters on individual farm is not typically economical for smaller dairies. Another challenge for anaerobic digestion is also posed by Reidhead (2010) where it establish that there is little doubt that as livestock manure is increasingly managed in liquid form, the carbon footprint of these animal industries increases greatly, and that burning a pound of methane (CH_4) combusted yields 2.75 pounds of carbon dioxide (CO_2), and CO_2 dramatically boosts global climate change. But in terms of greenhouse gas emissions, Wright-Pierce (2005) reports that none of the dairy manure options considered will produce more greenhouse gases than the natural decomposition of the manure, therefore, all options would be greenhouse gas neutral with the exception of anaerobic digestion which meets the goals of climate change plan of its study area. Greenhouse gases abatement measures are most effective if they reduce CH_4 emissions during storage (Amon *et al.*,2006 *in* Birchall *et al.*, 2008).

2.4.3.2 Use of Vegetative Barrier and Buffer Distance

The use of vegetative barriers (shelterbelts) and adequate setbacks and buffer distances in a dairy farm design increase the safe management of gaseous emissions component of waste generated from a dairy farm (Garcia *et al.,* 2004). Looking at the possible impact of gaseous emissions from one facility to the other: from one barn to another, from dirty areas to sensitive areas, New Zealand Ministry for Primary Industries (2013) recommends that buffer distances should be considered from the milk centre. Of critical note is the minimum distance of 45m to waste treatment and 20m to livestock section.

In a study by Samer (2010), buffer distance is found to complement effective gaseous emissions management from animal housing through prevailing wind in respect to the distance between two pens. A distance of about 15m is acclaimed be sufficient in preventing contaminated air from one pen and to another.

2.5 Design Approach to Waste Management on Dairy Farms

According to Kamel-Mahmoud (2006), holism is an approach to architectural design dealing with complex designs that takes a step beyond conceptual philosophizing and impression, expression and sculptured form to typical planning and design process that infuse inputs from other professionals to the architectural design process. It produce buildings that are environmentally responsive, productive, cost efficient while it enliven building occupants through simple planning, design and construction of buildings that are also easy in operation. Horn (1998), however, opine that holism looks at things in the context of the whole, seeking to understand the interconnections between the various parts that make up the whole with the aim of striking a balance. The following are the principles of holistic approach to design (Horn, 1998):

i. *Cyclical*: Look at how to encourage the repair, reuse and recycling of elements at every level.
ii. *Time Period:* This looks at the overall long term benefits and effects, rather than only the superficial short-term gains. This can be called a life cycle approach to design.
iii. *Context:* This principle prescribes that designers need to approach every design solution with freshness and open mindedness, flexibility and an ability to continue learning to achieve a sustainable design outcome.

iv. *Diversity:* is important to a holistic approach to design, it is less concerned with the quantity of diverse elements, but rather with the number of beneficial connections made between these components.

In proffering design solutions to the complex issue of sustainable waste management on dairy farm, the study conducted on Pretty (2007), Bylin *et al.*(2004), Menalled *et al.*(2008), Esfandiari *et al.* (2011), Rogers (2008) and El-Haggar (2007) reveals considerations to site planning of dairy farms for sustainable waste management and its corresponding indicators; these are layout design, orientation and zoning considerations. Also, the studies conducted on Barker (1998), Brião and Granhen-Tavares (2007), Ndegwa and Harrison (2002), Bickert *et al.*(2000), Carlsson (2005), Ludington (2004), Gay (2009), Jacobson *et al.*(2003), Birchall *et al.*(2008), Rong *et al.*(2014), Graves *et al.*(2014), Cook and Nordlund (2004), Garcia *et al.*(2004), Lenkaitis (2012) and Samer (2010) reveals measures to designing dairy farm facilities for sustainable waste management with its corresponding parameters; these are in terms of spatial design of facilities and the use of enveloping design elements. From the review, however, the research extract elements that integrates the site planning and facilities design in achieving sustainable waste management on dairy farms and thereby term it as integrated design consideration for sustainable waste management on dairy farms; these are accessibility (alleys and races) measures, considerations for integrated drainage/rainwater management, interior drainages, integration of waste management technology, and the use of proper waste treatment facility.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

This chapter extensively describes choices of research methods and justifies them in relation to alternative choices in answering the research questions posed in *section 1.6.* It proffers measures underpinning the collection of data, understanding and interpreting those data. Fig. 3.1 shows the research onion which is used as the major guide in building up the research.

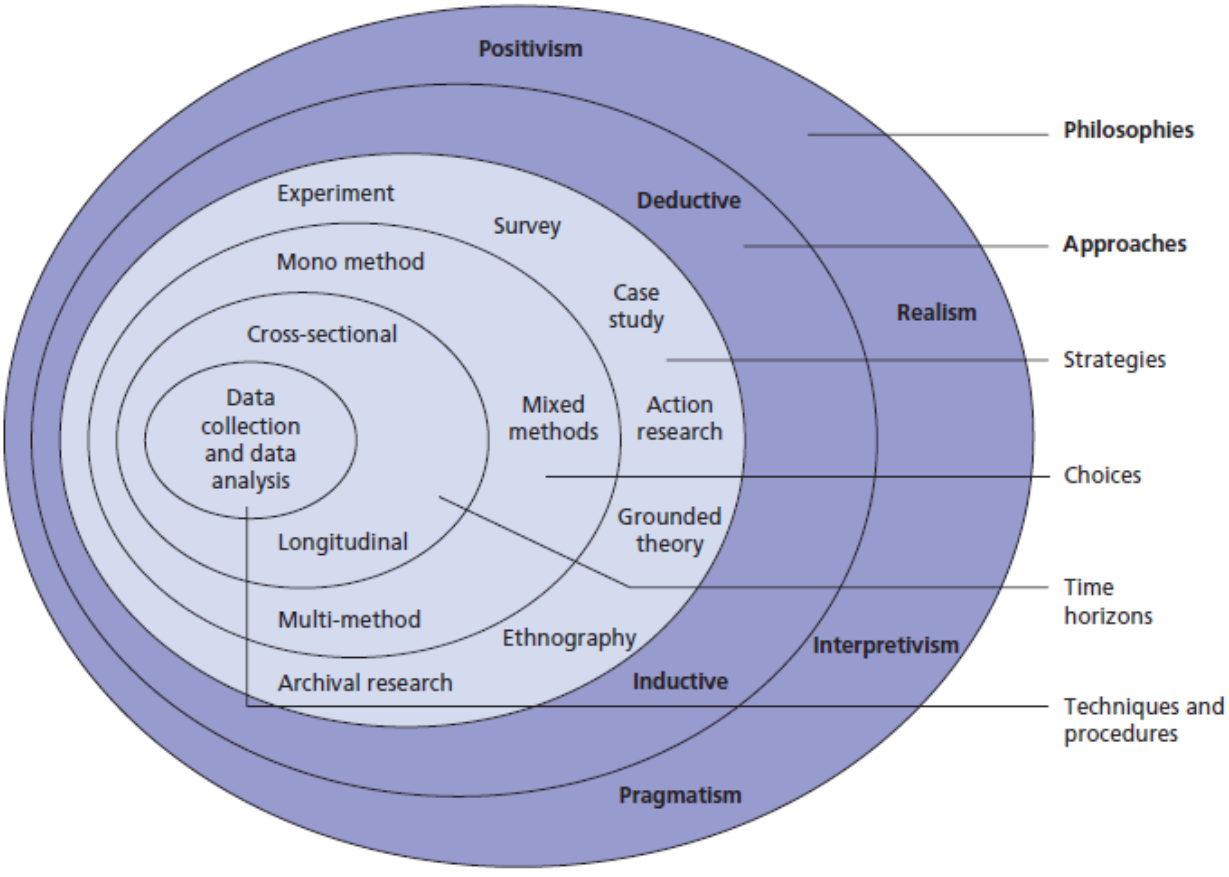


Figure 3.1: Research Onion

Source: Saunders et al. (2009)

This research seized pragmatism as research philosophy. According to Saunders *et al.* (2009), pragmatic research philosophy is mainly concerned with appropriate methods regardless of any static rules for research question to be answered, stating that the ontology (nature of reality of the research: design considerations for enhancing sustainable waste management on dairy farms in northern Nigeria), epistemology (acceptable knowledge in the field of the research: finding out real life situation of waste management on dairy farms in northern Nigeria and how sustainable waste management on dairy farms in northern Nigeria could be enhanced using design considerations), and axiology (research process of enquiry in achieving credible results: viable research technique in data collection and procedure for data analysis) to be adopted all depends on the research question enumerated on *section 1.6*. While Mkansi and Acheampong (2012) stress that pragmatic research owes prominence on practical research, theory and practical implications.

The nature of the knowledge developed by this research is qualitative. Qualitative research turn the world into a series of representations, including field notes, interviews, conversations, photographs, recordings and memos to self. It studies things in their natural settings, attempting to make sense of or interpret phenomena in terms of the meanings people bring to them (Denzin and Lincoln, 2011:6 *in* Ormston *et al.,* 2013). Therefore, research methods used by this research is purely construed base on suitability of the said method to properly address the research questions.

3.1 Research Methods

The research purpose is exploratory, aiming to explore design considerations for enhancing waste management on dairy farms from the results gotten out of a descriptive studies of dairy farms in Northern Nigeria.

According to Saunders *et al.* (2009), an exploratory research has literature review and interviews as principal ways of conducting the research. While the descriptive aspect is about developing skills of evaluating data and synthesising ideas. These ideas could be from observations. This research is thus a descripto-exploratory studies. This section thus elucidate plans for answering the research questions.

Case Study Research Method

The research adopted case study method, with the view toinvestigate thephenomenon of waste management within the real context of existing large scale dairy farm in northern Nigeria using multiple sources of case farms to proffer empirical evidence for research findings.

The research adopts multiple case study. Multiple case study, however, is focused on need to establish generalized findings where the findings in one study can be inferred on others (Yin, 2003 *in* Saunders *et al.*,2009). Owing to the peculiarities of this research, three (3) samples are thus used, picked purposively to gain useful, credible data and within available resources.

Research Variables

To set stable grounds for the research to achieve its aim on *section 1*.4, the research variables are used in establishing theory about the effectiveness of adopted independent

variables in enhancing the dependent variable on each case farm. The variables used are thus as follows:

i. ***Dependent Variable****:* The dependent variable in this research is sustainable waste management on dairy farms design.

ii. ***Independent Variables****:* these are the vehicle variables. The independent variables are thus:

   a. Site planning considerations for waste management

   b. Facilities design considerations

   c. Design measures and considerations for waste handling.

3.2 Population

The population of samples possible to be used in this research are all large scale dairy farms in Nigeria. These are dairy farms that according to Hamilton *et al.*(2010) are made of cattle environment; housing, cattle yards and laneways, and pastures; manure storage and handling facilities which deals with manure, effluent and wastewater; feed centre for processing and bulk storage of cattle rations; animal health section which comprise of vaccination, isolation unit, observation area, treatment area and storage space for veterinary cattle treatment; milk house (milk centre) where cows are milked and the first bulk storage for freshly harvested milk; processing plant where harvested milk is processed into finished dairy product; and other farm ancillaries like on and off-loading bay, dips and crushes.

3.3 Sampling

The sampling technique however adopted is judgmental (non-probability) sampling, where purposive option is used adopting the typical case option. According to Saunders *et al.* (2009), judgmental sampling best enables a research to answer research question(s) and to meet research objectives by enabling the Researcher's judgment to select case to be studied and can be used to answer research questions of "what" and "how" (as those inherent in this research).

Case Study Selection Criteria

The research selects cases based on two targets cities of northern Nigeria: these cities are Nassarawa and Kaduna. The research thus adopts Köster and Wolff (2012) characteristic for a large scale dairy farming in choosing the cases guided by the research scope outlined in *section 1.6*, the farms that resulted are thus:

1. Nagari Integrated Dairies Ltd, Keffi, Nassarawa
2. Niyya Farms, Kaduna
3. Lamda Farms, Kaduna.

Other considerations for this selection is:

Ease and Secured Accessibility: this criteria ensures that all cases established are located in a peaceful and stable location where the life and health of the researcher is to a large extent guaranteed and the ease on the farm management to approve the request for the case study.

3.4 Credibility of Research Findings

Reliability

Reliability of findings used in this research is ensured heeding keen caution to the following threats to reliability (Robson, 2002 *in* Saunders *et al.*,2009).

i. Subject or participant error (timing): the timing to discourse research interviews with respondents is chosen at a time the respondents are on break, feeling restful and in the mood to have a social time-out.
ii. Subject or participant bias (bosses influence): the interview questions are crafted artistically to guise inquiry of research data against the respondents feeling of been at risk of saying the wrong thing or portraying a negative image of the farm.
iii. Observer error (structure): a checklist is developed by the research to properly craft areas of research enquiry. This enquiry are photographed or diary noted for illustrative and narrative purposes.
iv. Observer bias (selfish affiliations): research ethics are adhered to strongly in ensuring there is no bias in either data collected or analysis.

Validity

Means of achieving validity of findings used by this research is by sticking to the research dependent and independent variables.

3.5 Procedure for Data Collection

As established on *section 3.3,* data collection tool that could be used for an inductive research could be observation and interviews. However, this data collection technique is called triangulation. According to Saunders *et al.* (2009), triangulation is the use of different data collection technique within one study to answer a particular research question.

Observation

This research used primary participant observation. Primary participant observation is a method of data collection which involves the researcher been there in time, systematically observing, recording, describing, analysing and interpreting observered phenomenon and it rhymes well with a qualitative research (Delbridge and Kirkpatrick, 1994 *in* Saunders *et al.*,2009). The guide used in the observation hence used in the research is shown in *appendix C*.

3.6 Procedure for Data Analysis

Analysis of qualitative data is a subject of the research approach (Yin, 2003 *in* Saunders *et al.*,2009). As this research adopts an inductive research approach on *section 3.3*, analytic induction is thus used as data analysis method. According to Saunders *et al*. (2009) analytic induction is an intensive examination of a strategically selected number of cases so as to empirically establish a phenomenon. Owing to the peculiarities of this research, issues of waste management on dairy farms in northern Nigeria is thus established, the level of sustainable waste management on dairy farms in northern Nigeria is also revealed and informed recommendations proffered.

Means of the actual analysis seized by this research is template analysis which according to Saunders *et al.* (2009) is a procedure of qualitative analysis essentially with a list of codes or categories representing themes revealed from data collected. The method used to portray analysis is narrative analysis which according to Saunders *et al.* (2009) depends on the research questions and objectives used in exploring linkages, relationships and constructed

explanations that naturally occur within a narrative accounts where fragmentations of categories and themes may be rendered unnecessary.

At the end, the means of data display and analysis is achieved through the production of interviews and observation summaries, categorisation of data by themes and structuring an order for the narrative.

By extensively examining issues of waste management on dairy farms in northern Nigeria, this research build up theory as to the current nature of waste management on dairy farms in northern Nigeria, ascertain how much sustainable waste management design considerations are imbued in dairy farm designs in northern Nigeria and build up an informed recommendations for enhancing sustainable waste management on dairy farms in northern Nigeria.

Owing to the nature of the research, an inductive approach is upheld which according to Saunders *et al.* (2009) is an approach that holds the primary concern to build up theory that is adequately grounded in data collected and in analysing qualitative data and commencing research through collecting and exploring data without a predetermined theoretical or descriptive framework.

CHAPTER FOUR

4.0 DATA PRESENTATION

This chapter presents data gotten from the three cases studied: Nagari Farms, Keffi, Niyya Farms Kaduna and Lamda Farms Kaduna.

4.1 Nagari Farms, Keffi, Nasarawa State

Nagari farms is located on the Gauta/Nikka Road, Keffi in Nassarawa state. It covers about 20hectares of land. It is a mechanically based operation farms, with the herringbone milking parlour approach. It operates an 8hrs shift with a grand capacity of about 500cattle. Their breeds of dairy cattle are purely Friesians, which are the best in milk productivity. At the moment, they have a fifty number (50) milking cattle and twenty (20) dry cows. They produce mainly cultured milk known also as yoghurt with an average of about 10,000liters per production per week. Plate II shows the 3D of the farm.



Plate II: 3D View of Nagari Farms, Keffi

Source: Researcher's Fieldwork (2015)

4.1.1 Design Strategies for Waste Management on Nagari Farms

From the established measures for achieving sustainable waste management on dairy farms from literature on *section 2.4,* which establish preferred considerations and measures for reducing waste generation, frequent waste evacuation and sustainable waste treatment through their respective indicators, using the independent variables established on *section 3.2.3* this section presents the data gotten from Nagari farms through these considerations and measures.

4.1.1.1 Site Planning Considerations for Waste Management on Nagari Farms

This section looks the site planning considerations of Nagari farms based on:

i. Site layout
ii. Orientation of farm facilities
iii. Zoning.

i. Site Layout

Road networks on the farm connects major parts and segments of the farm together. It connects the processing area to the products store which gives clear access out of the farm, as well as transcending to the livestock area where it reaches around the cattle on and off-loading bay. Figure 4.1 show the site plan.

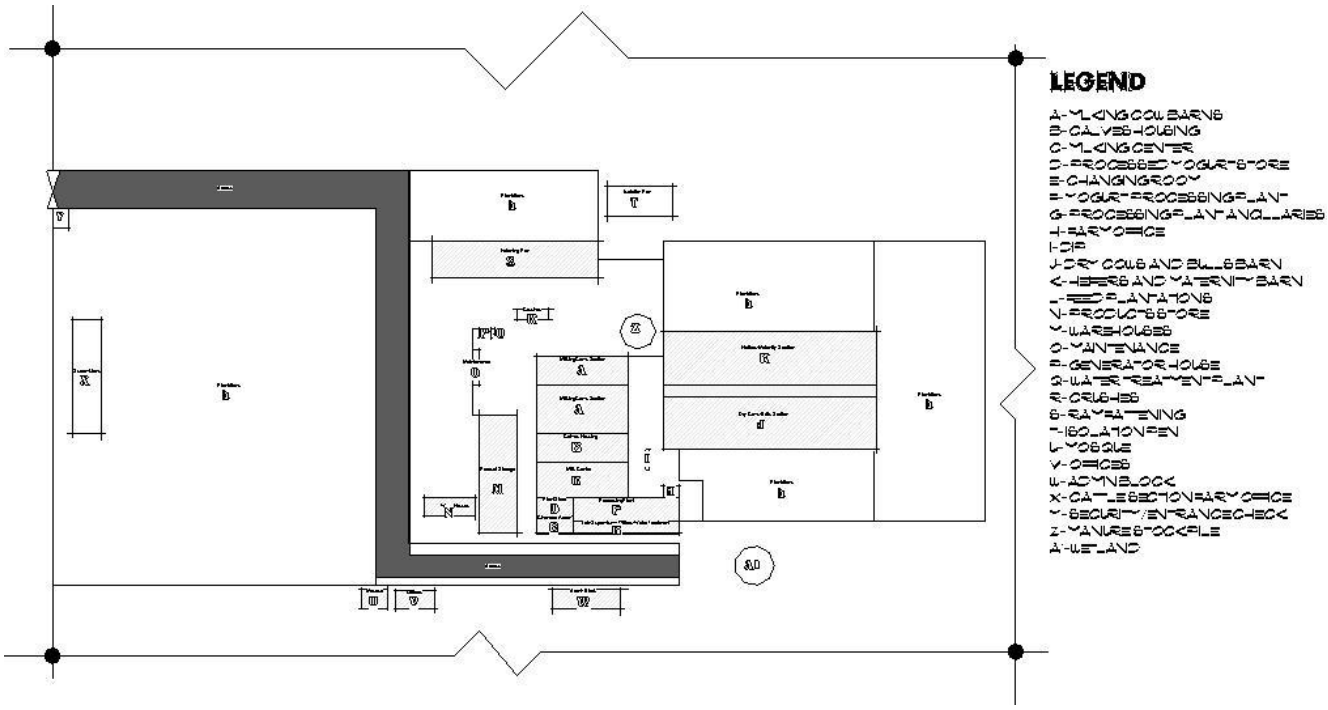


Figure 4.1: Site Plan Sketch, Dairy Section of Nagari Farms

Source: Researcher's Fieldwork (2015)

Facilities on the farm are seen to have topographical elevation considerations. The most critical waste producing facilities (barns) located at lowest points while those with less or no waste generating capacity (admin areas) are located at the higher elevations.

Vegetation around the farm are trees that surrounds the farm, thereby ensuring boundary tightness. Within the farm, the grasses on paddock land for cattle grazing and weed grasses forms the on-farm vegetation. There isn't vegetation or barrier within the farm facilities; the design could be said to be too compacted with no windbreaks and adequate buffer distances between facilities. Of crucial note is the livestock area directly attached to milk center and processing plant. Plate III shows the vegetation on Nagari farms



Plate III: Vegetation in Nagari farms

Source: Researcher's Fieldwork (2015)

ii. Orientation of farm facilities

All buildings on the farm are oriented to same axis, where the wider sides faces east-west, except for the warehouses and workshops which are oriented to north-south axis.

The barns are oriented so as its wider side faces east-west thereby exposing the major part of the barns to solar radiation.

The milk related areas are also oriented as the barns to the wider side of the building facing east-west. As shown on the site plan on figure 4.1

iii. Zoning

The location of facilities generating similar waste on Nagari farms are designed to make the barns zoned in a single cluster with close proximity to the milk centre; which produces manure and effluent. The processing plant also is zoned in a very close proximity zone to

the milk centre; which produces wastewater. Zoning of facilities is conspicuous on the different sections of the farm for hygiene and functionality reasons. The critical hygiene areas are designed to be easily assessable only for workers of that particular area, so also is the livestock area. Making transition from one confined staff section to the other highly controlled.

4.1.1.2 Facilities Design Considerations for Waste Management on Nagari Farms

This section presents reports on the design considerations in enveloping farm facilities as adopted by Nagari farms design. This is presented based on:

i. Spatial barn design

ii. Enveloping design elements.

i. Spatial barn design

The spatial design of the cattle barn adopts a housing design approach where the barn is mostly clustered.Head-to-head configuration of 4-row housing rows and feeding strip along the row and water trough by the side of the barn is how the barns are designed. The barn is designed to have a service alley for feeding the cattle. Between the cattle stalls, the alley is plain. Figure 4.2 shows a sketch of the barn.

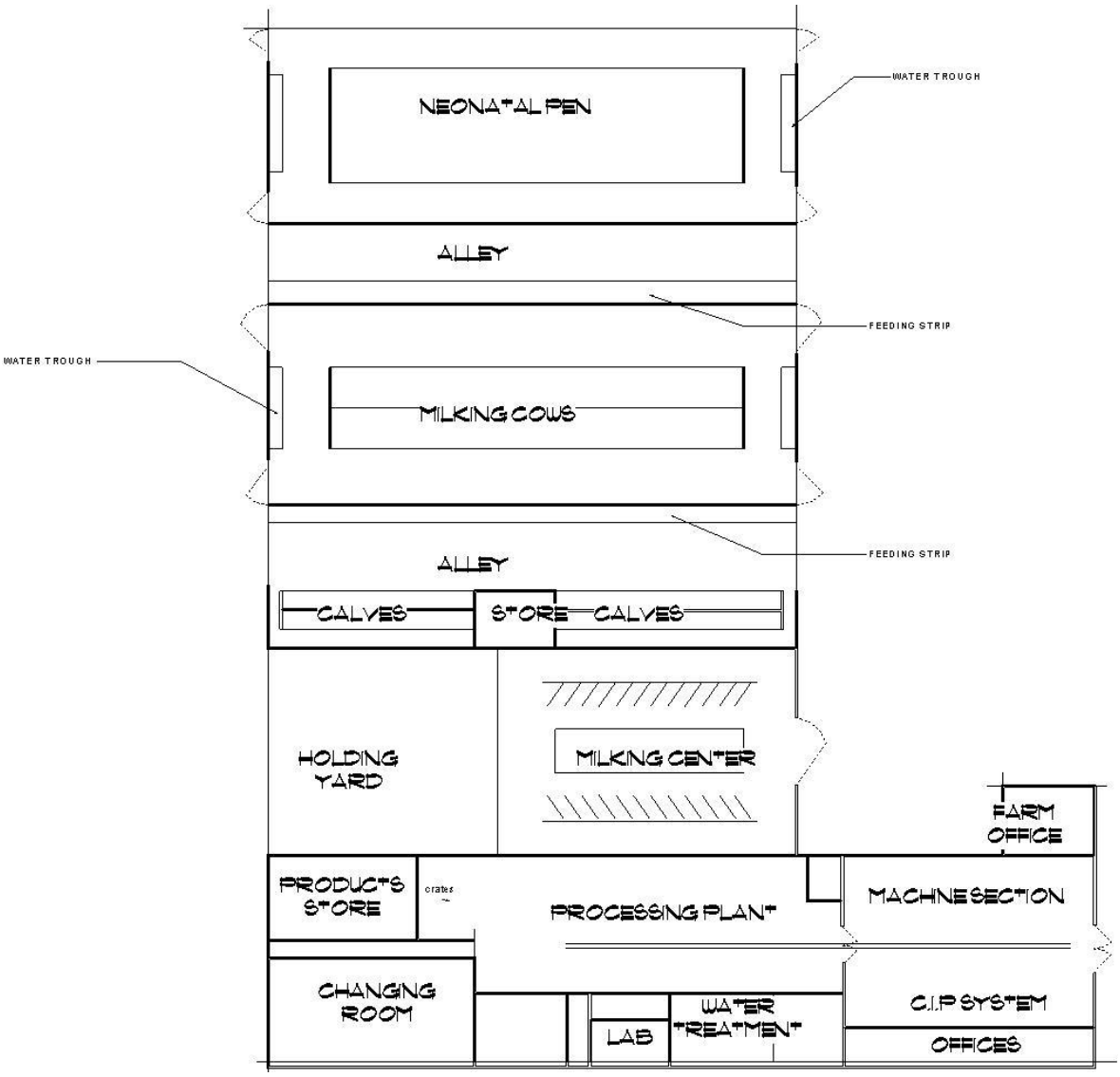


Figure 4.2: Sketch of Barn Design, Nagari Farms

Source: Researcher's Fieldwork (2015)

ii. Enveloping Design Elements

Coupled with the wall height system used in the barns, negative pressure ventilation system is adopted by using fans to blow out exhaust air out thereby creating negative suction of air. Plate IV shows indoor air circulation fans in barns.



Plate IV: Box Fans on Nagari Farm Barns

Source: Researcher's Fieldwork (2015)

In the barns, the exterior walls are completely open with steel stanchions and steel pipes demarcations. While in the interior, dwarf sandcrete walls with simple plastering are used in creating spatial organization of the interior spaces. So also is the walling considerations of the milk centre. Plate V shows the wall design of animal housing of Nagari farms.



Plate V: Cattle Barn Design Approach of Nagari Farms

Source: Researcher's Fieldwork (2015)

The roof in the livestock section is of two types, a mono-pitched covering the link between milk centre and calf housing and a ridge cap model. Although the ridge gap is about 200mm in size. In the processing plant, a majorly gable roof is used with a raised area of machine areas for high rise window/suction fans. Plate VI shows the ridge cap gap design of the barns.



Plate VI: Roof Ridge Cap Design of Barns, Nagari Farms

Source: Researcher's Fieldwork (2015)

The floor in the barn is relatively rough in texture, with no defined texture pattern, it is made of concrete. However, the floor could simply be said to be flat, with no visible slope to any direction or drainage point. Along the alley, a curb is used in demarcating cattle lying area from alley area.

While in the milk centre, the floor is also made of concrete, its texture is also rough as that of the barn with very negligible slope to the drain attached to the wall. And in the processing plant, the floor is tiled, smooth and drains in a very gentle slope to a gutter drain (plate VIII).

4.1.1.3 Design Measures and Considerations for Waste Handling on Nagari Farms

This section present report regarding the design measures and considerations adopted by the Nagari farm design in waste handling. This is based on:

i. Accessibility

ii. Consideration for integrated drainage/rainwater management

iii. Interior drainages

iv. Integration of waste management technology

v. Waste treatment facility.

i. Accessibility

Within the barns, accessibility and circulation is primarily used is an alley of about 3.6m used as access for workers using wheel barrows in manure evacuation. Plate VII shows the alley of Nagari farms barn



Plate VII: Service Alley of Nagari Farms Barns

Source: Researcher's Fieldwork (2015)

The farm design do not exactly use races network, however, in access to the farm dip, there is a race of about 750mm(Plate VIII) and also on the holding yard for on and off-loading bay the race used in controlling cattle movement is about 750mm.



Plate VIII: Farm Dip, Nagari Farms

Source: Researcher's Fieldwork (2015)

ii. Considerations for Integrated Drainages/Rainwater Management

Consideration for an integrated waste collection system is not incorporated in the design of the farm. The collection system is however disjointed. The barns uses scrape method of manure collection and conveyance using wheel barrows, although no effluent collection and conveyance infrastructure (Plate IX). Also, there is no consideration for sloped waste collection neither is there any consideration for gutters. But in the milk centre, the pit of the herringbone parlour system has a sloped drains at both ends.



Plate IX: Effluent Spills from Barns in Nagari Farm

Source: Researcher's Fieldwork (2015)

The farm premises of the livestock area has no consideration for diverts, curbs, dikes, culvert or pipes. The barn designs has no terraces or any means for diverting rainwater. Although, around the administrative area and processing plant is a gutters for collecting and conveying rainwater. Plate X shows drainage network around admin block of Nagari farms.



Plate X: Drainage Network around Admin Block of Nagari Farms

Source: Researcher's Fieldwork (2015)

iii. Interior Drainages

Drainages for effluent collection is not used on the barns' interior, the effluent is left to flow freely around the premises (plate VII). Wash water from the processing plant is collected using a centralized gutter. And wastewater from equipment and utensils washing is managed using the clean-in-place technology. Both of which are finally channelled out to wetland. Plate XI shows wastewater collection in processing plant of Nagari farms



Plate XI: Central Gutter Drain in Processing Plant of Nagari Farms

Source: Researcher's Fieldwork (2015)

iv. Integration of Waste Management Technology

In the processing plant, a clean-in-place (c.i.p) system is used to reduce wastewater generation, as shown on plate XII. However, the farm do not use any waste reduction technology in term of gaseous emissions like anaerobic digesters or solid-liquid separator.



Plate XII: C.I.P System of Nagari farms

Source: Researcher's Fieldwork (2015)

vi. Waste Treatment Facility

The waste treatment facility of the farm is not constructed. It is not integrated in the farm design; manure is handled as stockpiled using aeration, effluent is treated by implied natural process of decomposition while wastewater is directed and treated on a wetland around the processing plant and livestock section. Plate XIII show manure stockpile of Nagari Farms



Plate XIII: Manure Stockpile in Nagari farms

Source: Researcher's Fieldwork (2015)

4.2 Niyya Farms, Kaduna

Niyya Farms is located at KM 60, at around Gadan Mallam Mammam, along the Kaduna-Abuja Road. It covers more than 50hectares of land. Their barn facility have a grand capacity of about 800cattle. It basically adopts the manual milking approach and the use of bucket canisters in transporting the milk. They milk the cows twice a day. They maintain a twenty number (20) milking cattle of White Fulani, Friesian Holstein and Mont Billiard breeds with a grand milking productivity output of about 200liters/day. Plate XIV shows a 3D view of Niyya farms.



Plate XIV: 3D View of Niyya Farms, Kaduna

Source: Researcher's Fieldwork (2015)

4.2.1 Design Strategies for Waste Management on Niyya Farms, Kaduna

This section looks at the practical application of design strategies for waste management on Niyya Farms through the established measures from literature on *section 2.4*, which establish preferred considerations and measures reducing waste generation, frequent waste evacuation and sustainable waste treatment through their respective indicators using the independent variables established on *section 3.2.3* this section presents the data gotten from Niyya farms through these considerations and measures.

4.2.1.1 Site Planning Considerations for Waste Management on Niyya Farms

This section looks the site planning considerations of Nagari farms based on:

i. Site layout
ii. Orientation of farm facilities
iii. Zoning.

i. Site Layout

The design uses a road network of about 7.5m wide as circulation route around farm premises. This route connects the barns, milk centre, feed centre, processing plant and other farm ancillaries. Figure 4.3 demonstrate in a site plan sketch.

The farm design is loose with no windbreaks but adequate buffer distances between facilities. Of crucial note is the barns for matured cattle has clear span of about 10m and in the calves/heifers area around 5m span is allowed. And the design has a distance of more than 20m from the processing plant area to the cattle barns.

Vegetation around the farm are mostly scarce trees and weed grasses around the farm premises. In creating demarcation and to achieving screening, masquerade trees are used as barrier surrounding the processing plant, shielding it from other sections of the farm. Plate XV shows vegetative barrier around processing plant of Niyya farms



Plate XV: Vegetative Barrier around Processing Plant, Niyya farms

Source: Researcher's Fieldwork (2015)

ii. Orientation of Farm Facilities

The barns are oriented to same axis, where the wider sides faces east-west so as to expose major part of the barns to solar radiation and wind directions. While the processing plant and milk centre areas are oriented to north-south axis (figure 4.3).

iii. Zoning

Barns are designed to be in the same zone. Of note is zoning of processing plant to milk centre, where they are zoned on different zones; processing plant located close to the barns while been far away from the milk centre.Figure 4.3 demonstrate in a site plan sketch.



Figure 4.3: Site Plan Sketch, Dairy Section ofNiyya Farms

Source: Google Earth (2016)

In locating facilities on the farm, processing plant is located at the highest topographical elevation, the barns and farm ancillaries at middle elevation and milk centre at the lowest

elevation. And feed centre and manure stockpile are at the side relatively around same level to livestock area. Figure 4.3 illustrates in site plan.

4.2.1.2 Facilities Design Considerations for Waste Management on Niyya Farms

This section presents reports on the design considerations in enveloping farm facilities as adopted by Niyya farms design. This is presented based on:

i. Spatial barn design

ii. Enveloping design elements

i. Spatial Barn Design

The barns are designed as individual units in a semi-detached way. It adopts housing approach of loose housing. From the spatial planning of the barn (general mature cow section), open lounging is adopted using head-to-head organization, no cubicle but an open cow lying/living area with an open lot where it serve as exercise lot and water trough area. Within the barn, the design use a single alley for serving the feeding strip, and the barn uses an exercise lot where the water trough is located. While the calves and heifers section is designed in individual seclusions are used against the setting in the general mature area. The spatial design of the section uses gutter drains along the service alley. Figure 4.4 shows a sketch of the barn

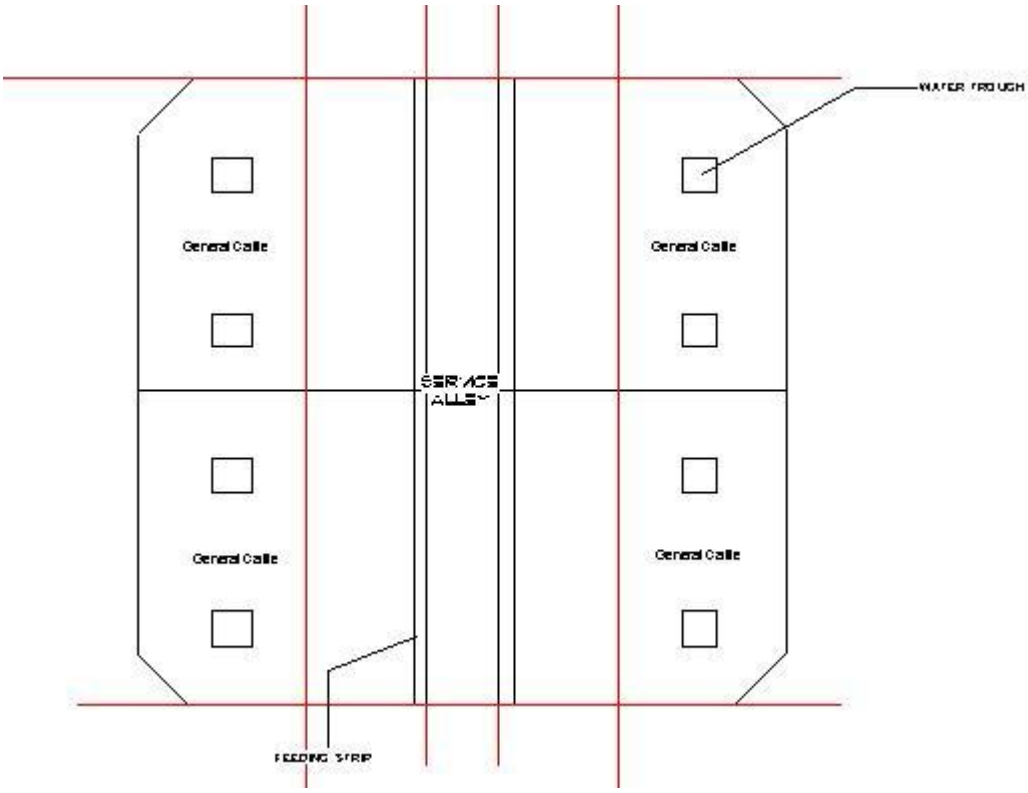


Figure 4.4: Barn Sketch, Niyya Farms

Source: Researchers Fieldwork (2015)

ii. Enveloping Design Elements

Open wall height design system is used on the barns using steel stanchions and steel pipes on matured cattle barns and in the calves/heifers section dwarf sandcrete walls are used in creating spatial organization of the interior spaces. So also is the walling considerations of the milk centre. While the roof design used in the barns section of general matured cattle section is a simple gable roof with no ridge gap opening or eave over-shot while the roof in the calves/heifers section is of eaves over-shot design with an open gap of about 300mm. In the processing plant, a gable roof is used. Plate XVI shows the walling design used on the barns.



Plate XVI: Walling Design for Livestock Section, Niyya farms

Source: Researcher's Fieldwork (2015)

The flooring in the lying area of the barn is relatively rough with no defined texture and made of concrete. However, the floor could simply be said to be flat, with no visible slope to any direction or drainage point. While in the milk centre, the floor is bare laterite. In the processing plant, the floor is tiled and smooth.

4.2.1.3 Design Measures and Considerations for Waste Handling on Niyya Farms

This section present report regarding the design measures and considerations adopted by the Niyya farm design in waste handling. This is based on:

i. Accessibility

ii. Consideration for integrated drainage/rainwater management

iii. Interior drainages

iv. Integration of waste management technology

v. Waste treatment facility.

i. Accessibility (Alleys and Races)

The accessibility within the barns for matured cattle is an alley of about 3.6m (see figure 4.4). And for thecalve and heifers barns, an access of about 3m is used. While the accessibility connection means around livestock farm premises to cattle ancillary facilities do not exactly use the races design, the crushes and cattle dip use a race of about 750mm in controlling cattle movement. Plate XVII shows the cattle dip.



Plate XVII: Cattle Dip, Niyya Farms

Source: Researcher's Fieldwork (2015)

ii. Consideration for Integrated Drainage/Rainwater Management

There is no consideration for integrated drainage system in the farm design. The collection and conveyance systems are disjointed. Consideration for rainwater management also is not visible. The design of the farm premises do not use curbs, diverts or gutters in managing run-off on the livestock section. Although, gutters are used around the processing plant

area. For the barn, the design do not use any means of terrace or design element in protecting the barn interior from driving rain.

iii. Interior Drainages

The use of drainages in the interior of the farm facilities is no considered in the design of matured cattle barns. The farm uses scrape method of manure collection and conveyance using wheel barrows, effluent collection and conveyance is not considered on the mature cattle barns and simply allowed to gravity flow around the adjoining areas while effluent from calves/heifer section channelled through gutters to a natural wetland as shown in plate XVIII. Wash water from the processing plant is collected using pipe drain points. And wastewater from equipment and utensils washing is managed using the clean-in-place technology. Both of which are finally channelled out.



Plate XVIII: Gutter Network around Heifers Section, Niyya farms

Source: Researcher's Fieldwork (2015)

iv. Integration of Waste Management Technology

The farm use a clean-in-place system in reducing quantity of wastewater generated. However, the farm do not use any waste treatment technology that reduces gaseous emissions generation. Plate XIX shows the C.I.P system of Niyya farms.



Plate XIX: C.I.P System of Niyya Farms

Source: Researcher's Fieldwork (2015)

v. Waste Treatment Facility

The waste handling facility of the farm is not integrated; manure is handled as stockpiled by implied natural process of decomposition using aeration, effluent is treated by implied natural dry-up and waste water is disposed of on a natural wetland. Plate XX shows the manure stockpile.



Plate XX: Manure Stockpile, Niyya Farms

Source: Researcher's Fieldwork (2015)

4.3 Lamda Farms, Kaduna

Located at KM 25, Dogon-Dawa Road, Rigachikun, Kaduna. It covers about 200hectares out of which dairy section occupies about 10hectares. They maintain a 100cattle of Friesians, Simmentals and their breeds, Bramans breeds of cattle. 36 cows of which are

milked and the others been bulls, dry cows, calves and the bramans which are basically used for beef. They adopt the mechanical milking system of herringbone parlour approach with a 2times operation schedule. They liaise with neighbouring Fulani for their processed cultured products of about 200liters a day. The farm adopt the zero grazing system where the animals are supplied all their feed requirement to the barn. Plate XXI shows a perspective of Lamda farms



Plate XXI: Perspective of Lamda farms

Source: Researcher's Fieldwork (2015)

4.3.1 Design Strategies for Waste Management on Nagari Farms

From the established measures for achieving sustainable waste management on dairy farms from literature on *section 2.4,* which establish preferred considerations and measures for reducing waste generation, frequent waste evacuation and sustainable waste treatment through their respective indicators, using the independent variables established on *section 3.2.3* this section presents the data gotten from Lamda farms through these considerations and measures.

4.3.1.1 Site Planning Considerations for Waste Management on Lamda Farms

This section looks the site planning considerations of Lamda farms based on:

i. Site layout
ii. Orientation of farm facilities
iii. Zoning.

i. Site Layout

The farm generally has no defined road network. All facilities on the farm are placed on the site generally without any defined route connecting them.

The farm design is widely loose with no windbreaks but adequate buffer distances between facilities. Of crucial note is the livestock area where barn in the general matured cattle section is at about 20m from each other and the much farther to the bulls section and the calves/heifers area. And the processing plant is also very farther away from the livestock area, generally. So is the milk centre. As demonstrated on the site plan sketch on figure 4.5

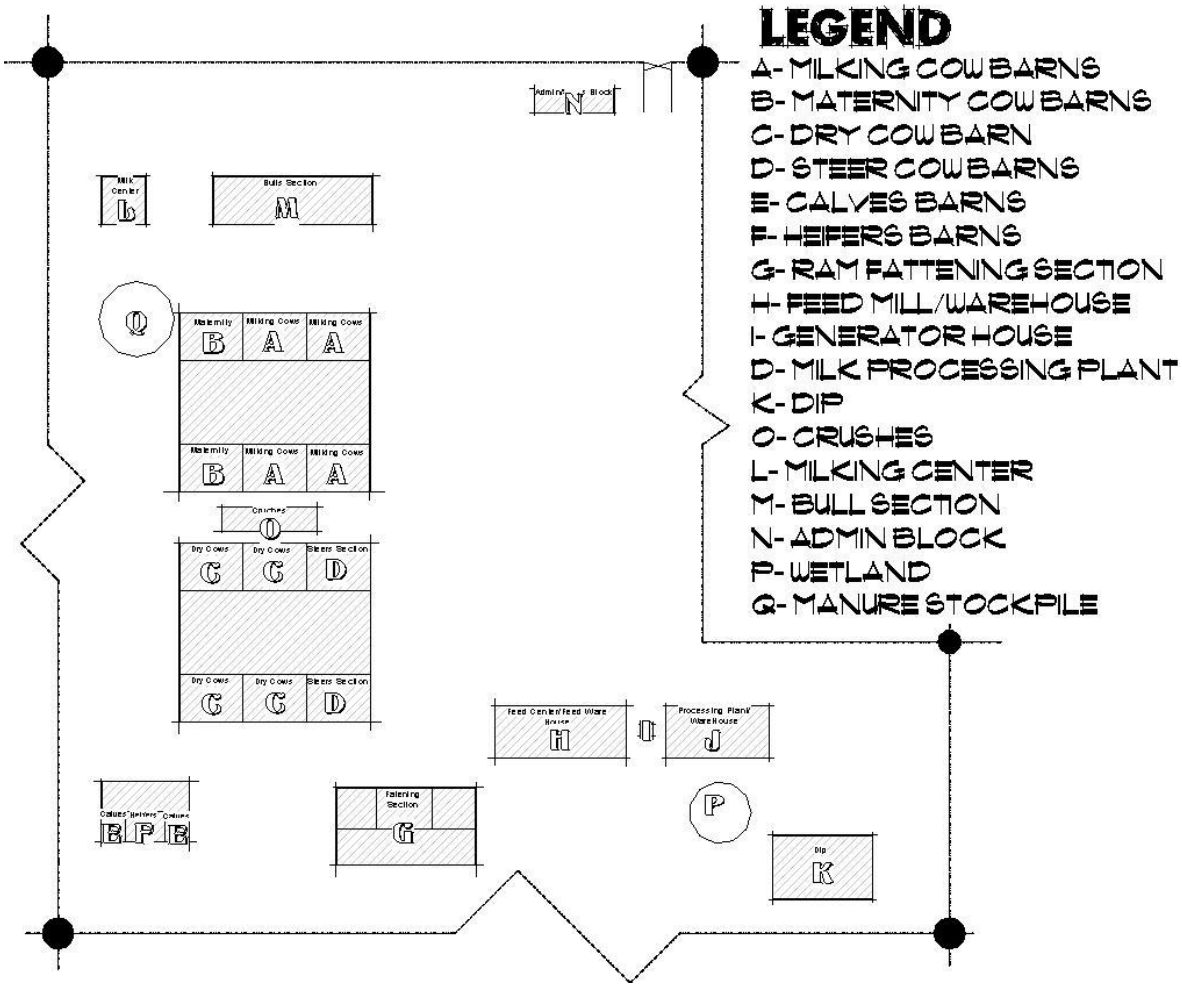


Figure 4.5: Site Plan Sketch, Dairy Section of Lamda Farms

Source: Researcher's Fieldwork (2015)

Vegetation around the farm are scarce trees randomly around the farm surroundings. Within the farm is mostly less maintained weed grasses. There however isn't vegetation or barrier within the farm facilities. Plate XXII shows the vegetation around the farm premises



Plate XXII: Vegetation around Lamda Farm Premises

Source: Researcher's Fieldwork (2015)

ii. Orientation of Farm Facilities

All the barns on the farm are oriented to same axis, where the wider sides faces east-west thereby exposing the major part of the barns to solar radiation. While the processing plant and milk centre are oriented to north-south axis. The milk centre areas are also oriented to north-south axis against the barns that the wider side of it facing east-west. Figure 4.5 illustrates in site plan sketch.

iii. Zoning

The design locates facilities generating similar waste on the farm by zoning barns together, creating a zoning relation between the barn housing milking cows to the milk centre and as well creating a manure treatment area in the barns zone. The milk centre to processing plant however are zoned differently and also the cattle dip is zoned to the feed centre zone, creating a close proximity to the processing plant.

The design locate milk centre and admin block on the highest topographical elevation, the matured cattle barns, bulls barns and the crushes on the semi-middle elevation and the calves/heifers barn located on the middle elevation. The milk processing plant is located on the lowest elevation together with the feed centre and the cattle dip.

4.3.1.2Facilities Design Considerations for Waste Management on Lamda Farms

This section presents reports on the design considerations in enveloping farm facilities as adopted by Lamda farms design. This is presented based on:

i. Spatial barn design

ii. Enveloping design elements.

i. Spatial barn design

The spatial design of the cattle barns is not designed based on the head-to-head or tail-to-tail row number design nor the stalls design. The barns for matured cattle is designed in a row of cubicle units having a double banking style with service alley as corridor. The barns housing calves/heifers of the farm is designed as a row of cubicle units for group calves housing with loose housing and exercise lot incorporated.While the barns housing the bulls is designed as a row of cubicles housing individual bulls a cubicle per bull. Figure 4.6 shows a sketch of the barn.

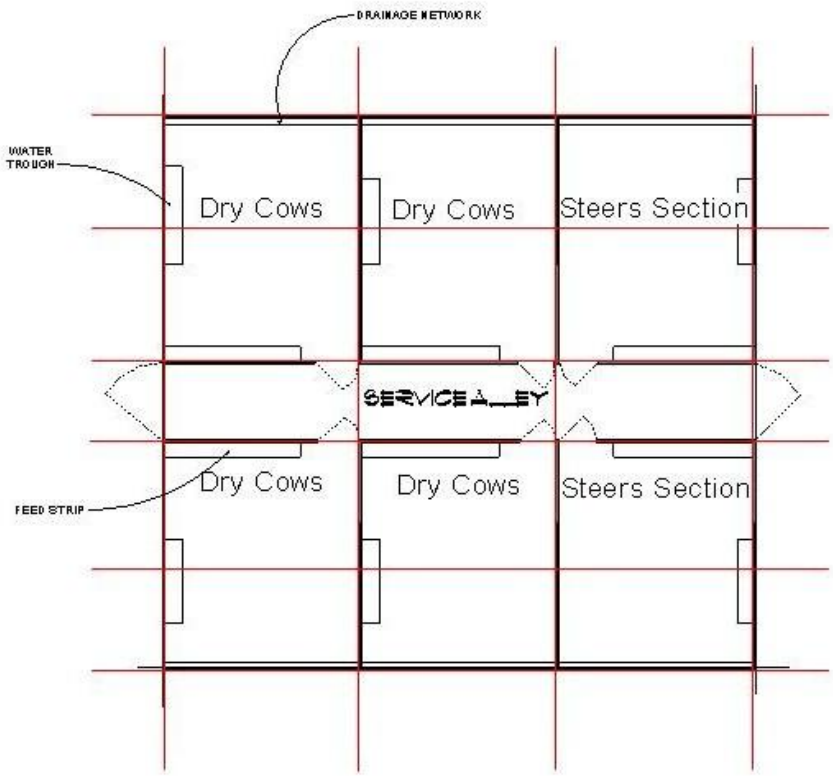


Figure 4.6: Barn Design Sketch, Lamda Farms

Source: Researcher's Fieldwork (2015)

ii. Enveloping Design Elements

Walls used in the design of the barns for matured cattle on the farm are of dwarf sandcrete wall of about 1200mm high and upper part completely open with steel pipes on the upper part. The bulls barn made of individual cubicles are walled in about $3/4^{th}$ wall height of about 2.1m with perforations and the other $1/4^{th}$ open and supported by steel pipes. While in calves/heifers section, the walling design is completely erected to roof height with large window fenestrations of about 1500mm by 1200mm, and about 1500mm open door way is used while blank walls used are used to demarcate between units. So also is the walling considerations of the milk centre. Plate XXIII show the housing units.



Plate XXIII: Barn Housing Approach, Lamda Farms

Source: Researcher's Fieldwork (2015)

The roof design on the barn for general matured cattle is a simple gable roof with no ridge gap opening or eaves overshot and so also is the roof in the calves/heifers barn and also the bulls' cubicle. In the processing plant, gable roof is used.

The flooring in the barns for matured cattle is relatively rough in texture, with no defined texture pattern, and it is made of concrete.However, the floor sloped very gently to a gutter drains (see plate XXV). While on the calves/heifers barns, the floor is bare, with no visible slope to any direction or drainage point. While in the milk centre, the floor is of concrete with no special treatment. In the processing plant, the floor is tiled and smooth.

4.3.1.3Design Measures and Considerations for Waste Handling on Lamda Farms

This section present report regarding the design measures and considerations adopted by the Nagari farm design in waste handling. This is based on:

i. Accessibility

ii. Consideration for integrated drainage/rainwater management

iii. Interior drainages

iv. Integration of waste management technology

v. Waste treatment facility.

i. Accessibility

The means for accessibility and circulation by the farm design within the barns for matured cattle is an alley of about 3m. In the calves/heifers barns, the design dictates a no interior circulation measure as the design is made in individual cubicles with a general access from the farm open premises. So also is the barns for bulls. Plate XXIV shows the alley of Lamda farms.

The use of races in the design is made on crushes used for minor veterinary operations as well as the access to the farm dip where a race of about 750mm is used in conveying cattle.



Plate XXIV: Barn Alley in Lamda farm

Source: Researcher's Fieldwork (2015)

ii. Considerations for Integrated Drainage/Rainwater Management

The farm design has no consideration for integrated drainage system. The waste collection infrastructure is disjointed with each waste category having its separate collection and conveyance system. The considerations for rainwater management around farm premises is sparingly made around the barn section for general matured cattle by using a gutter system. Though on a general note, the farm design has no consideration for the use of curbs or diverts in managing run-off around farm premises. Also, in the barn design, there is no terraces or any designed means of protecting barn interior from rain water influx (see plate XXIII).

iii. Interior Drainages

The farm uses scrape method of manure collection and conveyance using wheel barrows, effluent from the general matured cattle barns are designed to have gutters to channel it out of the barn environment, but on the calves/heifers barns and bulls' barns, no such consideration is made. Waste water from the processing plant has no infrastructural consideration for collection and conveyance. Plate XXV shows the effluent collection gutter.



Plate XXV: Effluent Spills from Barn, Lamda farms

Source: Researcher's Fieldwork (2015)

Wash water from the processing plant is handled by mopping. And wastewater from equipment and utensils washing is managed by manually carried it out in buckets to be disposed of on natural wetland. Plate XXVI shows the interior of processing plant of Lamda farms. There however isn't any consideration for managing runoff around the farm premises



Plate XXVI: Processing Plant, Lamda farms

Source: Researcher's Fieldwork (2015)

iv. Integration of Waste Management Technology

The farm do not use any technology that reduces waste generation.

v. Waste treatment facility

The waste treatment on the farm is not integrated. The manure generated from the farm is handled as stockpiles using aeration, effluent has no tangible consideration for treatment and waste water is handled on a natural wetland. Plate XXVII shows the manure stockpile.



Plate XXVII: Manure Stockpile, Lamda Farms

Source: Researcher's Fieldwork (2015)

CHAPTER FIVE

5.0DATA ANALYSIS

This chapter analyses the data of design strategies for waste management acquired from the cases visited and studied presented on *chapter four*. The primary motive of analysing the data is to proffer objective response to the research questions posed on *section 1.6*

5.1 Comparative Assessment of the Design Strategies for Waste Management on Nagari Farms, Niyya Farms and Lamda Farms

To assess the effectiveness of the design strategies implemented on the case farms, three architectural considerations are used as major heads with their respective variables and inherent specific strategies. The table 5.1 shows the assessment using ascale factor for the assessment used is good, fair and poor.

Table 5.1: Assessment of Design Approach for Waste Management on Nagari Farms, Niyya Farms and Lamda Farms

S/N	RESEARCH VARIABLE	NAGARI	NIYYA	LAMDA
	SITE PLANNING CONSIDERATIONS FOR WASTE MANAGEMENT			
1.	**Site Layout**			
a.	Road networks	Good	Fair	Poor
b.	Considerations for topographical features	Good	Fair	Poor
c.	Considerations for vegetation and buffers	Poor	Poor	Poor
2.	**Orientation**			
a.	East-West barn orientation	Good	Good	Good
d.	North-South orientation for farm facilities	Poor	Good	Good
3.	**Zoning**			
a.	Similar waste generating facilities location	Good	Fair	Fair
b.	Staff Facilities	Good	Fair	Poor
	FARMSTEAD FACILITIES DESIGN CONSIDERATIONS FOR WASTE MANAGEMENT			
1.	**Spatial Design**			
a.	Barns	Fair	Poor	Poor
b.	Milk centre	Good	Poor	Fair
2.	**Enveloping Design Elements**			
a.	Floors	Fair	Poor	Fair
b.	Walls	Fair	Fair	Fair
c.	Roofs	Good	Fair	Poor
	DESIGN MEASURES AND CONSIDERATIONS FOR WASTE HANDLING			
a.	Accessibility (Alleys and Races)	Fair	Fair	Poor
b.	Consideration for integrated drainage/rainwater management	Poor	Poor	Fair
c.	Interior drainages	Fair	Fair	Fair
d.	Integration of waste management technology	Fair	Fair	Poor
e.	Waste treatment facility	Poor	Poor	Poor

Assessment Factors: Good, Fair and Poor

From the assessment on table 5.1, site planning considerations for waste management is most implemented throughout the cases, followed by farmstead facilities design considerations for waste management and the least implemented been design measures and considerations for waste handling. Within the site planning architectural considerations,

orientation of farm facilities variable is most implemented followed by site layout variable and the least implemented is the zoning variables. While within the farmstead facilities design considerations, the use of enveloping design elements is the variable mostly implemented and the spatial design least implemented. And the design measures and considerations for waste handling shows that using interior drainages is the most implemented, followed by integration of waste management technology and means of accessibility, while the least is the waste treatment facility.

5.1.1 Indicative Measure of Efficiency of the Design Approach Implemented as it Impacts the Hierarchy forSustainable Waste Management on Nagari Farms, Niyya Farms and Lamda Farms

This section is explicit in pointing out the specific design variable and strategy that affects each hierarchy for achieving sustainable waste management established on *chapter two* on the cases studied. The discussion that follows shows how the respective design strategies form a major predictor index for wholesome and effective waste management on dairy farms (see table 5.2, table 5.3 and table 5.4).

Table 5.2: Reducing Waste Generation Using Design Considerations for Waste Management on Nagari farms, Niyya farms and Lamda farms.

S/N	**Waste Management Hierarchy**	**Nagari Farms**	**Niyya Farms**	**Lamda Farms**	**Design Considerations**	
					Variable	**Strategy**
1.	Use of Waste Reduction	Use of C.I.P	Use of C.I.P	None	Measure and Consideration	Integration of Waste

	Technology				for Waste Handling	Management Technology
2.	Achieving Dry Indoor within the Farm Facilities	i. Open height wall design on barns and dwarf walls on calves' cubicles. ii. Gable roof with ridge cap gap on all the barns.	i. Open height wall on matured cattle and dwarf wall on calves and heifers section. ii. Gable roof with no ridge gap opening on matured cattle section and eaves overshot with opening on calves and heifers section.	i. Dwarf walls on matured cattle section, 2/3 dwarf walls on bulls section and cross ventilation on calves and heifers section. ii. Gable roof all over the farm with no roof opening.	Farmstead Facilities Design Considerations for Waste Management	Use of Enveloping Design Elements
		i. Orientation of barns, milk centre and processing plant take wider sides to east-west axis.	i. Barns orientation is east-west axis, milk centre and processing plant is north-south axis.	i. Barns orientation is east-west axis, milk centre and processing plant is north-south axis.	Site Planning Considerations for Waste Management	Orientation of Farm Facilities
3.	Flooring Design	Rough concrete floor all over the barns.	Rough concrete floor all over the barns.	Rough concrete floor on matured cattle section and bare laterite on calves and bulls section of the barns.	Farmstead Facilities Design Considerations for Waste Management	Use of Enveloping Design Elements

From table 5.2 above, it could be deduced that integrating waste management technology in the design of dairy farms reduce the quantity of waste generation by reducing the quantity of wastewater generation. For wastewater generated from washing processing utensils, Nagari and Niyya farms use clean-in-place technology where the washing system

is mechanized and washing resources (water and disinfectants) highly recycled and periodically discharging the worn-out washing resources by channelling it to a natural wetland (an expanse of land for wastewater disposal). Lamda farms do not use the clean-in-place technology however takes out the wastewater manually in buckets to be disposed of also on a natural wetland.

In reducing the generation of greenhouse gases and breeding of harmful pathogens to cattle, achieving dry indoors may be implemented using walling and roofing design to enhance better air flow, and also the orientation of the facilities which is used in exposing the facilities to take advantage of wind direction and solar path. On Nagari Farms, all exterior walls of the livestock section is open to full height except in the calves housing where dwarf walls of about 1200mm is used. Same is used on Niyya Farms design. But on Lamda Farms, the matured cattle section is open to about half wall height while on the calves/heifers section, the walling system is completely different as it is all built up with consideration for windows of about 1500mm by 1200mm and about 1200mm open door way. In the bulls section however, walling is made to about 1200mm from the floor and then perforated walls of about 600mm and the rest of the wall height open to the roof level.

The roof design of livestock section of Nagari Farms is mainly a gable roof with ridge opening design. But the roof design of livestock section of Niyya Farm is different base on the size of the cattle; for matured cattle it is a simple gable roof with no special touch, while on the calves/heifers section, the consideration is an overshot roof with a roof gap of about 300mm. And on Lamda Farms, the roof design is gable all over the livestock section. Orientation of the livestock section, milk centre and processing plant of Nagari Farms are to same axis, where the wider sides faces east-west. On Niyya Farms, while all the barns on

livestock section faces east-west, the processing plant and milk centre faces north-south. So also is the orientation on Lamda Farms.

The type of flooring design used on the respective facilities also is established to impact on the rate of emission of greenhouse gases, by using concrete floors with texture and dutch-groove pattern on livestock housing. Flooring pattern of livestock building of Nagari Farms has no defined pattern, though it is relatively rough and made of concrete. So also is the flooring pattern of Niyya Farms. On Lamda Farms however, while the general section for matured cattle is having a concrete rough floor with no defined pattern, the calves and bulls section has no concrete flooring.

Table 5.3: Efficient Waste Handling Process Using Design Considerations for Waste Management on Nagari farms, Niyya farms and Lamda farms.

S/	Waste Manageme	Nagari Farms	Niyya Farms	Lamda Farms	Design Considerations	
					Variable	Strategy

N	nt Hierarchy					
1.	Spatial Design of Farm Facilities	i. Clustered farm design approach. ii. Open lounging housing approach on barns with both freestalls and loose housing approach.	i. Dispersed design approach. ii. Open lounging housing approach on the barns with loose housing all over the barns.	i. Dispersed design approach. ii. Open lounging housing with loose housing option on all other parts of the barns except the bulls section where individual housing is used.	Site Planning Considerations for Waste Management. Farmstead Facilities Design Considerations.	Site Layout. Spatial Design.
2.	Integrating Waste Management Infrastructure	i. Gutter drainage network on processing plant for wastewater collection/conveyance. ii. No infrastructure considerations for manure collection/conveyance in animal housing.	i. Drainage points on processing plant for wastewater collection/conveyance. ii. No infrastructure considerations for manure collection/conveyance in animal housing.	i. No collection/ conveyance infrastructure in the processing plant ii. Drainage gutter on part of livestock section for effluent collection. iii. No infrastructure considerations for manure collection/conveyance.	Measures and Considerations for Waste Handling.	Considerations for Integrated Drainages/rain water Management Use of Interior Drainages. Accessibility (Alleys and Races).
S/N	**Waste Management Hierarchy**	**Nagari Farms**	**Niyya Farms**	**Lamda Farms**	**Design Considerations** **Variable**	**Strategy**
3.	Accessibility Network for Waste Collection	i. Road networks around the farm. ii. Alley circulation within livestock	i. Road networks around the farm. ii. Alley circulation within livestock	i. No road networks on the farm premises. ii. Alley circulation within livestock	Site Planning Considerations for Waste Management. Measures and Considerations for Waste Handling.	Site Layout. Accessibility (Alleys and Races).

		buildings.	buildings.	buildings		
4.	Zoning and Location of Farm Facilities	i. Barns cluster zone. ii. Barn-milk centre zone. iii. Milk centre-processing plant zone	i. Barns cluster zone. ii. Barn-milk centre zone. iii. No milk centre-processing plant zone	i. Barns cluster zone. ii. Barn-milk centre zone. iii. No milk centre-processing plant zone	Site Planning Considerations for Waste Management	Zoning of Farm Facilities

From table 5.3 above, it could be deduced that the configuration in spatial design of farm facilities affects the effectiveness of waste evacuation process. Site layout could be used in achieving a good flow of waste handling process through the farm design approach of either cluster or disperse. The cluster makes for ease and simpler waste handling. On the facilities design, the use of loose housing with two-row tail-to-tail configuration and central alley. Also, the use of herringbone milking parlour gives an easier and more effective base for waste evacuation. The design of the barns on Nagari Farms adopts open lounging with loose housing system, designed as a cluster in rows and feeding strip with no exercise lot, with 4-row head-to-head configuration along an alley with a feeding strip. And Niyya Farms barns are designed as a loose system where no defined stalls is used and the feeding strip place along the alley with the water trough in the exercise lot, with head-to-head arrangement. While on Lamda Farms, the barns are designed as units to contain the cattle in bulk and an exercise lot integrated with the cattle living space, eating and water trough space.

The use of topographical elevations as a means to control influx of waste impact from one function to another is considered on Nagari Farms as it locates livestock section and waste

treatment area at the lowest farm elevation making milk centre at a middle elevation and processing plant at the highest elevation. Contrary is on Lamda Farms where the Milk centre is at the highest site elevation and livestock section at the middle and processing plant at the lowest elevation and approximately at same elevation with the dip. While on Niyya Farms, processing plant is on the highest elevation, livestock area at the middle at same elevation with all yard ancillaries, the milk centre at the lowest elevation.

The considerations for integrated drainages and rainwater management affects the means of effluent and wash water in terms of collection and conveyance and also rainwater management through controlling driving rain access to the interior of farm facilities thereby limiting the quantity of the waste. The drainage systems used on Nagari Farms, Niyya Farms and Lamda Farms designs are all disjointed in approach. Rainwater management however, is also not considered on all case farms; Nagari farms has no considerations for run-off diverts nor any measure for preventing rainwater influx to the barn interiors, so also is Niyya Farms and Lamda Farms. Interior drainages for collecting effluent on Nagari and Niyya farms have no infrastructural considerations on the livestock section. Although, Lamda has a gutter drainage on the section for their matured cattle. In terms of wastewater from utensils and equipment wash and floor/sanitary wash water, Nagari farms use central gutters in their milking and processing plant to channel out the wash water, Niyya uses drain points on the floor using underground drainage system to collect and channel it out of the premises, and Lamda have no infrastructural consideration for collection and conveyance of waste water.

Establishing an elaborate accessibility network of roads around farm premises and the use of alleys within barns and races within livestock section promotes the effectiveness of

waste evacuation from farm facilities. The use of road network on Nagari farms is made to connect all relevant facilities on the farm needing vehicular usage. On Niyya farms also, road network is used to connect the farmstead facilities. But on Lamda farms, there is no road network around the farm premises. Within waste generating buildings/facilities, Nagari, Niyya and Lamda farms are designed to consider alley design in serving as means of circulation and accessibility with an alley size of about 3m - 3.6m. Races design are used only in cattle handling ancillaries; the dip and crushes on all case farms. The races have an estimated size of about 750mm.

And zoning facilities with similar waste generation potential makes the waste evacuation process more effective and controlled. Barns on Nagari Farms, Niyya Farms and Lamda Farms are zoned at same zone giving the livestock areas generally a touch of single unit in function. Although, Nagari Farms design zone milk centre and processing plant together and also locating the zone in close proximity to livestock area. But on Niyya Farms and Lamda Farms, milk centre and processing plant are zoned at different zoning unit. In terms of yard ancillaries zoning, while Nagari Farms and Niyya Farms zoned all ancillaries together, Lamda Farms zoned these ancillaries far away from one another.

Table 5.4: Sustainable Waste Treatment Using Design Considerations for Waste Management on Nagari farms, Niyya farms and Lamda farms.

S/N	Waste Management Hierarchy	Nagari Farms	Niyya Farms	Lamda Farms	Design Considerations	
					Variable	Strategy
1.	Waste Treatment Facility	i. Manure stockpile. ii. Natural	i. Manure stockpile. ii. Natural	i. Manure stockpile. ii.Natural	Measures and Considerations for Waste Handling	Waste Treatment Facility

		wetland treatment for wastewater and effluent.	wetland treatment for wastewater and effluent.	wetland treatment for wastewater and effluent.		
2.	Use of Vegetative Barrier and Buffer Distance	i. No vegetative barrier within the farm premises. ii. No buffer between barns and milk center, nor buffer distance between barns and processing plant.	i. Use of vegetative barrier around processing plant. ii. Disperse design with buffer distance between the barns and milk center, barns and processing plant.	i. No vegetative barriers all over the farm. ii. Disperse design with buffer distance between the barns and milk center, barns and processing plant.	Site Planning Considerations for Waste Management.	Site Layout.

From table 5.4 above, it could be deduced that the nature of waste treatment facility used on dairy farms determines the level of impacts of the waste on the environment. The use of an elaborate waste treatment facility for manure and effluent/waste water determines the level of impact of the generated waste on the environment and eco-system. Nagari, Niyya and Lamda farms do not use an integrated waste management system, they all stored and eventually treat wastes differently base on the nature of the waste. These farms all use aeration method as means for manure storage and treatment in a stockpile usually close to livestock section which is exposed to erosion and nutrient leaching around the farm and its surroundings and also makes for a bare emission of greenhouse gases and odour. As for effluent, while Nagari and Niyya farms have no considerations for capturing it and treating it properly, Lamda captures some of it and channelling it out without any consideration for storage and treatment. In the case for wastewater, Nagari, Niyya and Lamda farms do not

capture to store these water, instead they dispose of it on natural wetland. And spoilt production and also deadstock have no on-farm consideration for storage and treatment.

And finally, the layout design of a dairy farm with consideration for the use of vegetation around waste potent areas aids the sustainable treatment of the greenhouse gases emitted from the farm facilities by capturing them and the use of buffers in the layout design also could be used to achieve containment of waste on generating facilities before evacuation, thereby limiting influx from one facility to another. There are no much considerations for windbreaks and buffer zones on Nagari Farms; the design is clustered in approach. On Niyya Farms, the buffer distance between barns on the livestock section is about 15m and even more distance between livestock section and processing plant, although the buffer distance between the livestock section of calves/heifers area to milk centre is not as wide. However, on Lamda Farms, there is also no considerations for windbreaks the buffer distance between facilities is about 20m on the matured general cattle section to one another and even more distance to the calves section and bulls section.

Vegetation on Nagari Farms do not serve vegetative barrier function as the only conscious vegetation is the beautification using hedges around the administrative area. On Niyya Farms, vegetative barrier is used in barricading the processing plant from the livestock section, yard area and milk centre. But on Lamda Farms, no any form of conscious vegetation around the farm premises.

Generally, the discussion shows that site planning considerations for waste management are more required in establishing a dairy farm design that enhances sustainable waste management, then followed by design measures and considerations for waste handling and then farmstead facilities design considerations for waste management.

From the discussion presented above, it is shown that integrating waste management technology in the design of dairy farms reduce the quantity of waste generation by reducing the quantity of wastewater generation. In reducing the generation of greenhouse gases and breeding of harmful pathogens to cattle, achieving dry indoors may be implemented using walling and roofing design to enhance better air flow, and also the orientation of the facilities which is used in exposing the facilities to take advantage of wind direction and solar path. The type of flooring design used on the respective facilities also is established to impact on the rate of emission of greenhouse gases, by using concrete floors with texture and dutch-groove pattern on livestock housing.

The configuration in spatial design of farm facilities affects the effectiveness of waste evacuation process. Site layout could be used in achieving a good flow of waste handling process through the farm design approach of either cluster or disperse. The cluster makes for ease and simpler waste handling. On the facilities design, the use of loose housing with two-row tail-to-tail configuration and central alley. Also, the use of herringbone milking parlourgives an easier and more effective base for waste evacuation. The considerations for integrated drainages and rainwater management affects the means of effluent and wash water in terms of collection and conveyance and also rainwater management through controlling driving rain access to the interior of farm facilities thereby limiting the quantity of the waste. Establishing an elaborate accessibility network of roads around farm premises and the use of alleys within barns and races within livestock section promotes the effectiveness of waste evacuation from farm facilities. And zoning facilities with similar waste generation potential makes the waste evacuation process more effective and controlled.

The nature of waste treatment facility used on dairy farms determines the level of impacts of the waste on the environment. The use of an elaborate waste treatment facility for manure and effluent/waste water determines the level of impact of the generated waste on the environment and eco-system. And finally, the layout design of a dairy farm with consideration for the use of vegetation around waste potent areas aids the sustainable treatment of the greenhouse gases emitted from the farm facilities by capturing them and the use of buffers in the layout design also could be used to achieve containment of waste on generating facilities before evacuation, thereby limiting influx from one facility to another.

5.2 Summary of Findings

Base on the investigation conducted on the design strategies for waste management on the selected case farms in the research geographic delimitation of northern Nigeria to find out the real situation context of these strategies with the view to assess how they fare, the data analysed on *section 5.1* reveals shortcoming and inadequacies of the design of the case farms. Below are the enumeration of the findings:

1. The need for a dairy farm design where the layout considers elaborate circulation and accessibility as it makes for ease of waste evacuation; topographical features in locating farm facilities, the use of vegetative barriers and buffer distances as it enhance effective waste management on dairy farms.

2. A dairy farm design with east-west orientation for barns and north-south for others to seize positive advantages of natural flow of prevailing wind and solar movement as it promotes waste management on dairy farms.

3. The need for zoning of farm facilities to achieve efficiency in waste collection and eventual evacuation.

4. The need for a dairy farm design whereby spatial configuration of spaces captures and integrate design modalities achieving sustainable waste management on dairy farms.

5. The need for a design where roof design, walling design and fenestration configurations, and flooring designs are used as tools in promoting a wholesome and sustainable waste management on dairy farms. And

6. The need for designing standard farmstead facilities i.e waste treatment facility, barns, milk centre and processing plant that are integrated in modalities for waste handling process.

5.3 Evolution of Design Framework

From the discussion on design approach to waste management on dairy farms on *section 2.5,* the skeletal of the design considerations are:

1. Site Planning Considerations for Waste Management on Dairy Farms

2. Farmstead Facilities Design Considerations

3. Design Measures and Considerations for Waste Handling.

From *section 3.1.1*the dependent variable is sustainable waste management on dairy farms, and the independent variables are adopted from design considerations established from literature are used to develop an observation checklist on *section 3.5.1,* to assess the effectiveness of implemented design approach on case farms, theanalysis on *section 5.1* andsummary on *section 5.2* reveals the relevance of strategies for waste management in

enhancing sustainable waste management on dairy farms. These shows that the measures and considerations for waste handling is highly deficient in dairy farms assessed, followed by the farmstead facilities design considerations for waste management and then site planning considerations for waste management.

Using the guide from literature and established deficiencies on the studied farms, a simplified and elaborate design solution to issues of waste management on dairy farms through a framework is developed. Design framework is an important tool employed in harmonizing complexity in multi-disciplinary design by simplifying the complex inter-disciplinary interrelation of design components to a context (Pimapunsri and Tichkiewitch, 2013; NatCen Social Research, 2012).

The framework developed is proposed as “Holistic Design Framework for Enhancing Sustainable Waste Management on Dairy Farm”. This framework is defined as a set of design strategies coined as a tool that harmonise the infrastructural requisite for the practice of sustainable waste management on dairy farms with contemporary concerns for animal welfare and productivity, and environmental protection to achieve a diverse cyclic resource flow that is time efficient within the context of a conceptual design philosophy that express planning and design process infusing guidelines and concerns from other professional stakeholders to produce a farm design that is environmentally responsive, productive, cost effective, visually appealing that also enliven the occupants.

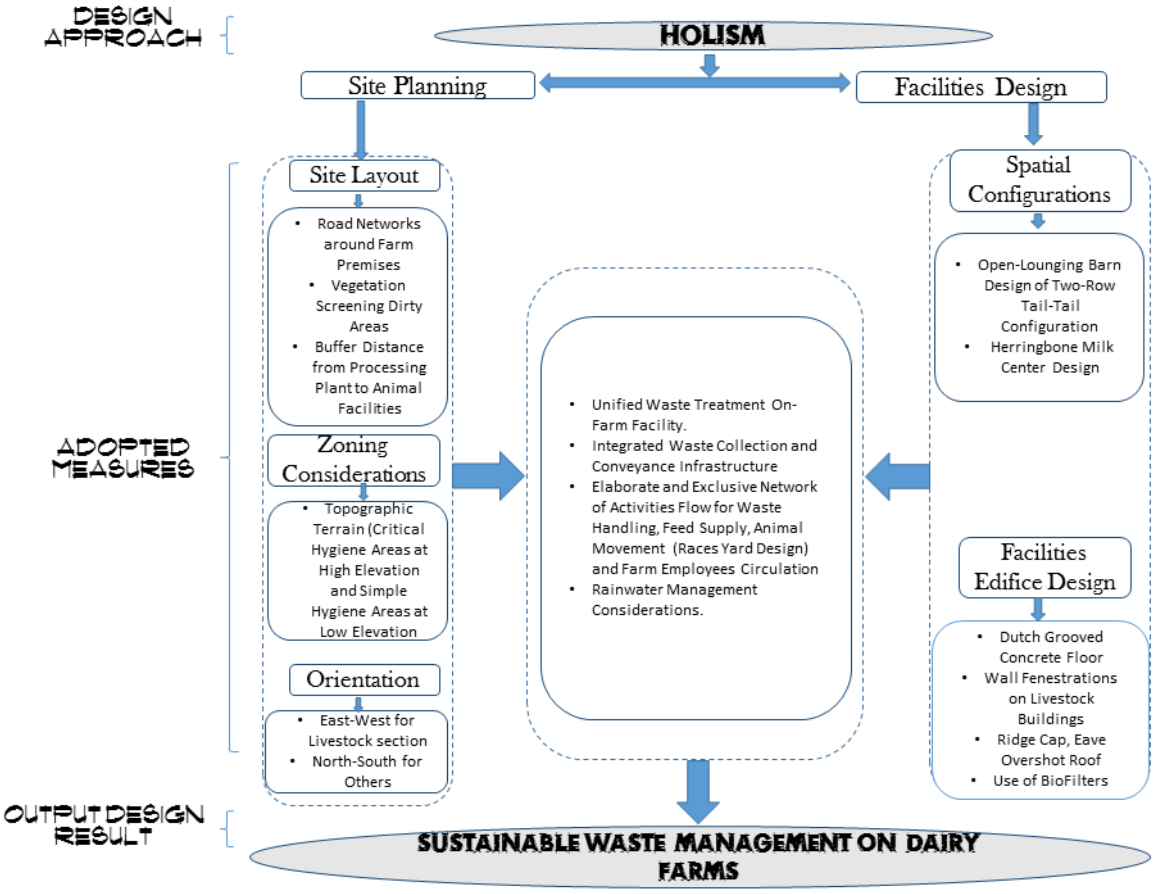


Figure 5.1: Holistic Design Framework for Enhancing Sustainable Waste Management on Dairy Farms

Source: Researcher's Sketch (2016)

From a general point of view, the framework propagates a farm design approach that is integrated in a loose way: it should have a touch of been a cluster of functions while at the same time retains adequate buffer distance between functions. As depicted on figure 5.1 the framework is made of the following elements, each of which bears its distinctive sets of parameters.

i. Site planning

ii. Building design, and

iii. Integrated design considerations.

An elaborate discuss of the framework is presented on *section 5.3.1, section 5.3.2 and section 5.3.3*

5.3.1 Site Planning Considerations for Holistic Design Framework for Achieving Sustainable Waste Management on Dairy Farms

Viable site planning considerations enhance the flow of activities and affect the efficiency of waste management practices and functionality on dairy farms. Such, the layout design of the farm, zoning and orientation of farm facilities are significant in ensuring efficient flow of activities and promotes sustainable waste management on dairy farms. Thus, this section view the procedure of site planning through the lens of functionality, aiming to establish a design that establish functional link between facilities and services on the site.

5.3.1.1 Layout Design

The site layout of a dairy farm have the primary function of establishing boundaries while creating and maintaining interconnectivity on the site. Road network around farm premises are considered as it serve a viable means of access to various parts of the farm, it promotes waste management in the same fashion it ensures functionality.

Road network circulation and accessibility consideration on dairy farm on site planning is about designing with clear consideration for demarcating the various accesses required on-farm in terms of vehicular circulation and accessibility. Vehicular circulation and accessibility on dairy farm should consider means of safe and efficient ingress and egress from the farm either for supplies or deliveries. Other consideration of vehicular circulation and accessibility on dairy farms however is serving employees and customers.

The use of vegetation ensures the provision of some level of containment and entrapment of waste at producing level. And buffer distance ensure adequate space between functions to prevent influx of activities. Furthermore, vegetative barriers are vital in ensuring boundary tightness of facilities on dairy farm. The consideration for the use of vegetative barriers however affect the effective containment of waste within a facility and form either a visual barrier or psychological barrier any of which could help in the entrapment of released greenhouse gases from the activity on a particular facility. While almost all facilities on dairy farm needs vegetative barriers, of special note is the waste handling facility where a lot of greenhouse gases and odour are generated in large quantities. The next important facility is the processing plant, where apart from the prevention of influx of unwarranted odour or gases, it gives the premises a feeling of hygiene and industrial sophistication. And generally, vegetation creates a heaven out of any environment: that applies on dairy farm designs as well.

In the layout design of a dairy farm, buffer distances are also significant considerations. It aid in the containment of activities within its hosting facility. Of special attention however is the buffer distance between processing plant/milk centre to animal facilities: there should be a distance of no less than 15m. Another buffer distance consideration is between livestock buildings, a minimum of about 15m is to be allowed between the considering facilities: this prevents the influx of unwarranted emissions from one building to the other. One major consideration also, is the water source of the farm, a much significant distance should be allowed between the source and primarily the waste treatment plant.

5.3.1.2 Orientation

In seizing advantages from prevailing wind and solar path, orienting buildings on dairy farm should be given due consideration. The wider sides of the barns on livestock section should be oriented to east-west direction, while other facilities should be oriented to north-south direction. Seizing these advantages, the orientation considerations on a dairy farm significantly affects the activities within the indoor of the building: it helps in maintaining dry indoor condition thereby drastically reducing waste impact.

Orienting similar buildings to same axis is the general guide as the building peculiarities are to a large extent the same. Livestock building are to be oriented having the wider sides facing east-west axis, this in justification is about using the solar radiation to aid in drying up of the interior space, coupled with the prevailing wind. While milk centre and processing plant however are preferred to hold the north-south orientation owing to the activities within the buildings of human employees and their need for thermal comfort and thereby employing measures for reducing heat gain.

5.3.1.3 Zoning Considerations

Zoning facilities on dairy farm afford the dairy farm design pockets of facilities base on activities which makes the general functionality of the farm more effective. Owing to the three zones inherent on dairy farm of dry zones, wet zones and dry/wet zones, zoning similar waste generating facilities together makes managing the facilities easier and much effective. And segregating between facilities base on the nature of its workers is also another zoning consideration and wet/dry zoning of facilities which zone facilities base on the nature of activities that happen within the facilities.

The terrain of the site should be analysed in considering how facilities should be zoned on site: at the point of site development concept. Looking at the nature of dairy farming and the facilities that makes up a dairy farm complex, the major facilities with high priority of consideration are the waste treatment facility, livestock section, milk centre and processing plant. These facilities are to be zoned base on the topographical condition of the site, ensuring the processing plant and water sources are at the highest elevation owing to the justification that it is the most sensitive facility of the farm. Followed by the milk centre considering how milk could be prone to possible contamination. Then the livestock section to the middle elevation of the terrain while the waste treatment facility at the lowest site terrain.

To expanciate, all livestock section comprising the different areas for the different categories of cattle are to be in the same zone. But this zone as a unit should strongly be related to cattle yard ancillaries and also the feed centre where the supply of cattle ration comes from. The consideration is that these facilities generate similar waste (manure and effluent). And milk centre should be zoned in between the livestock section and processing plant owing to the fact that it's a dual waste producing facility. The combined waste producing facilities in zoning should have a consideration for viable relationship to the waste treatment facility. The other zoning consideration is based on the nature of activity on a facility, like the livestock section is where the agriculturist and veterinarians along with sanitation workers dwell: which is not high rated in hygiene appearance. The other consideration id the milk centre and processing plant where food and nutrition professionals gain their forte: crowned very sensitive area/activity. A means of zoning

should be considered in differentiating these functional units while appreciating the intertwining and dependence of one over the other.

5.3.2 Facilities Design and Construction Considerations for Holistic Framework for Achieving Sustainable Waste Management on Dairy Farm

Building design as an element in the framework is mainly concerned with established considerations base on a building design that enhance waste management on dairy farm. As discussed, this is based on on-farm facilities, building edifice design, spatial configuration of facilities and waste collection infrastructure.

Design and construction considerations on individual facilities making up a dairy farm have a significant impact on the efficiency of waste management practices on the dairy farm. From the provision of supporting facilities, the building envelope design, accessibility considerations within the buildings up to the integration of waste collection infrastructure within the building designs: design consideration could be exploited in enhancing waste management on dairy farms.

5.3.2.1 Spatial Design

As facilities on dairy farm could form under either livestock section: barns, holding yards, dips, crushes/races, veterinary unit; intermediary area: milking centre; processing area: processing plant, packaging plant and warehouses; farm ancillaries: workshops, cafeteria/break area; farm utilities: water treatment plant, alternative electricity source; waste treatment facility; and administrative block. These facilities complement one another in either function or operation. While some facilities serve the primary function of forming

the vessel for the production and processing of milk products, other facilities however serve as structural support in aiding the process. Of note, for the effective operation of a dairy farm, all facilities are a need. Zooming closer into the facilities design, some of the facilities have established configurations models for spatial organization, and some models could be said to be more efficient over the others under some conditions.

The model of spatial configuration adopted on facilities in a dairy farm design goes a long way in dictating nature and efficiency of operation in that particular facility: in terms of waste management and functionality. Open-lounging in barns gain preference as it accords adequate considerations for cattle handling while also considering best management practice. On the cattle yard design also, the races model where holding yards and other outdoor cattle handling facilities are linked in defined and coordinated route also gain preference as it gives some level of control over cattle management and proffer viable base in accessibility for proper waste management practice.

When large scale farming is the consideration, a barn design approach of open lounging is more ideal as it balances space requirement, animal welfare and ease of waste management. On the part of the cattle yard however, a design approach with holding yards along with races is better as it balances efficient animal movement/handling with more effective measure for waste management. Looking at milk centre, herringbone design approach takes the crown as it balances simplicity in establishing, economic feasibility and measure for effective waste management.

5.3.2.2 Building Envelope Design

The edifice of the individual buildings making up a dairy farm in design have a significant impact on the efficiency of waste management within the said building, and cumulatively the entire farm. Of note, is the design considerations accorded to the flooring design, walling design and roofing design.

The design of components that makes up dairy farm buildings are significantly crucial in determining efficiency in waste management of the dairy farm. Of special note are the barns. A patterned flooring design made of concrete with dutch-groove pattern gain preference as it reduce air emissions and also aide animal welfare issues on dairy farms. The flooring design could have a central gutter collection system for effluent with a mild slope of about 5%. Nature of walling design used on dairy farm designs affects the efficiency of air exchange which helps in controlling indoor condition at different seasons. The use of dwarf walls with a height of about 1500mm could be used and the overall wall height should be at about 6m to the head course. Therefore, wall fenestrations should be designed with the aim to achieve dry indoors while creating absolute shelter for the cattle and other activities of the farm. While roof designs are also equally as important in establishing good indoor conditions through ensuring a design of roof with ridge cap gap or eave overshot, this is because as it promotes maintaining good indoor condition and emissions control within farm buildings using principle of stark effect, it also provides good cover against rainwater. Other consideration for the roofing is a measure for roof insulation, where by roof should be designed to insulate the interior from transmitted heat gain from the sun into the interior space.

As for other spaces, orthodox design considerations are simply applicable in achieving desired functionality and space utility.

5.3.3 Integrated Design Considerations for Holistic Design Framework for Achieving Sustainable Waste Management on Dairy Farms

Integrated design considerations bridge the lacuna between the site planning and farm buildings thereby harmonising the overall farm design as a single functioning complex while it proffers more base for sustainable waste management on dairy farms. The indicators for discuss under this element, however, are unified on-farm waste management facility, integrated waste collection and conveyance infrastructure and efficiently integrated accessibility network on the farm.

5.3.3.1 Unified On-Farm Waste Management Facility

The existence of a waste management facility is very crucial for sustainable waste management practice on dairy farm. Seizing advantages ranging from ease of establishing, accessible and affordable technique and a system that gives better control for waste management, manure treatment should be by composting. As a composting facility, there is better control of how waste is managed, air emissions are easily captured and neutralized using bio filters and commercial waste operation could even be made easier. For the liquid aspect, a treatment plant where the waste is collected, stored and treated should be provided, after which the environmentally safe liquid produced could be used in irrigation.

5.3.3.2 Integrated Waste Collection Infrastructure on Dairy Farm Designs

Waste collection infrastructure are the tools in consideration for effective waste collection and conveyance. An efficient waste collection infrastructure depicts the level of coordination in waste management process achieved by a dairy farm design. Hence, infrastructure for waste collection is seen on two fronts: the first been the nature of the waste to be provided with the said infrastructure and secondly the actual built infrastructure in terms of design and construction. Though, both goes hand in hand.

Integrated waste management system on dairy farms is a system whereby managing waste generated from a dairy farm is seen as a unit and is given a management consideration for handling as a unit also. Owing to the fact that there are different forms of material waste on dairy farm, each is considered with its handling peculiarities appreciated and then the whole system is integrated. The aspect of manure should be provided with adequate space sizes for alley and races, effluent should be provided with an integrated gutter system from the generating facility to treatment area and also wash water be provided with either the gutter or underground pipe system. The collected waste should eventually be handled as a unit to the treatment plant. Also, the use of control kerbs around manure related areas should be ensured as it prevents waste spills from the defined environment.

5.3.3.3 Integrated Accessibility Network Considerations

Means of accessibility around different parts of the farm and within various farmstead buildings in carrying out activities of handling waste, feed supply, animal movement and workers circulation is crucial in achieving a holistic farm design. While performing

effectively conceived function, accessibility means should be mutually exclusive giving the activities and functions an elaborate measure of compartmentalization.

Integrated accessibility is based on network flow of activity on one hand, and adequate space size that allows for unhindered flow on the other. Hence, the integrated system has a unified waste treatment for all waste generated from different parts of the farm collected through an integrated collection and conveyance infrastructure. The integrated accessibility integrates a network of flow in cattle handling, waste collection and conveyance, feed supply to various parts of the livestock area, and a segregated flow for different categories of farm employees.

CHAPTER SIX

6.0 MODEL DAIRY FARM, KADUNA DESIGN PROPOSAL/REPORT

This chapter presents a procedural step by step project initiation, design inception, actual design and report in demonstration of how design strategies are used in achieving sustainable waste management on dairy farm in response to achieving the research aim on *section 1.5.* The chapter utilized the research findings resolve on *section 4.4*as primary base in coming up with a demonstration of the practical applicability of these design strategieson the design proposal of the Model Dairy Farm, Kaduna.

6.1 Brief Formulation

Considering the issues inherent on dairy farm designs in Nigeria; efficient and wholesome waste management has so far proven elusive (Ugwu, 2010; Osotimehin *et al.,* 2006; Abubakar and Ismail, 2012; Ogundele and Jegede, 2011).There is the need for dairy farm designs that provides for waste treatment facility, considerations for integrated drainages/rainwater management, enhanced accessibility around and within farm facilities; a spatial design of farm from the site layout to the spatial design of unit facilities and the use of enveloping design elements on facilities; and finally, a design where zoning facilities is based on similar waste generation and also a farm design that uses vegetation around farm premises. While also proffering standard farmstead facilities designed based on efficiency of modalities in reducing waste generation, improvinghandling process and ensuring a safe and sustainable waste treatment of generated waste.

Base on the research findings in *section 5.2*, the need for a dairy farm design that effectively capture site planning parameters and facilities enveloping design parameters

inculcating the design strategies that ensures a sustainable waste management on dairy farms are established. Hence, the need for a dairy farm design that achieves functionality, harmonise the practice of wholesome and efficient waste management with animal welfare considerations and environmental degradation through spatial organisation and use of design elements. Also, the need for a design that adequately considers different categories of farmstead workers in their respective activities, demonstrating good understanding in the interrelationship of functions and activities while maintaining relevant links that adds up to a functional modern state of the art dairy farm. And, a design that consider appeal to architectural excellence, environmental assessment star rating, and a model for political will demonstration of the Nigerian industrial agricultural sectors' contribution and advocacy for global sustainability in the international community.

The herd size, conceived nature of farm operations, means of waste treatment, and handling frequency determine needed facilities on dairy farm (Bickert *et al.,* 2000). Looking at the scope of a modern large scale dairy farms, the functions required are the barns, cattle yard ancillaries, milk centre, processing plant, feed centre, veterinary/animal treatment unit, waste treatment facility, farm ancillaries, farm utilities and administrative block.

The barn for housing dairy cattle, regardless of cattle category (heifers, milking cows and dry cows; calving/maternity; post calving; sick/injured cattle; bulls) are generally made of resting space (stalls or lying area), feeding and water space, storage facilities / prep room (feed storage, health records and first aid supplies). The cattle yard ancillaries for coordinated handling of dairy cattle consist of drafting/sorting yards, dip, loading and unloading bay, supervision and crushes.

Milk centre for harvesting milk from the cattle composed of holding yard, parlour, milk room, equipment room, storage unit, office and rest room. Processing plant for the production of milk products basically made of tank room (raw milk), processing area, ingredients store, biochem lab, quality control, packaging materials/crates room, finished products store, changing/locker/toilets, manager office and machine room.

Feed centre facility for the bulk storage and processing of cattle rations consist of high moisture feed store, silage piles, dry hay store, nutrients and vitamins supplement storage, roller mill machine area (mixer and scales), processed feed storage bins and bulk bedding storage. Veterinary/animal treatment unit for vaccination, artificial insemination, pregnancy checks, deworming, dehorning, injections and examination of the dairy cattle, it is made of separation unit (holding / restriction yard), observation area, treatment unit (scales, cattle locks and medical store) and a veterinary office. Composting facility for solid waste treatment, it is made of mixing area, composting area, screening area, curing area, product storage and additional woodchips/saw dust store.

Farm ancillaries that aid the operation of the farm, it include warehouses, workshops. Farm utilities for supply of water and power: standby generator and water treatment plant. Administrative block for the overall coordination of the farm as an enterprise is composed of general reception, general manager, secretary, sales/accounting, departmental heads offices, marketing department and conference room.

Owing to the wide notion that northern Nigeria bears the agricultural strength of the nation on *section 3.7*, this demonstration is made to Kaduna state gaining more motive from the state governments' reassurances that high priority sectors of the states' administration includes industrial agriculture (Shiklam, 2015). Also, Köster and Wolff (2012) report finds

Kaduna is one of the states considered to be favourable to industrial agriculture of dairy farming and also the state is one of the top ranking in consuming dairy products. Thereby, this proposal is made to Kaduna state.

6.2Site Selection

This section presents process adopted in establishing suitable site for the design demonstration of the dairy farm development. It presents the selection process in terms of establishing the general location, then selection criteria before choosing the site.

6.2.1 Site Selection Criteria

The selection criteria are developed primarily based on Rogers (2008), the following criteria therebyresult:

i. Locality
ii. Land use
iii. Infrastructural amenities
iv. Consideration for sensitive areas
v. Topography
vi. Land size
vii. Soil type
viii. Security.

i. Locality: Within the large geographic boundaries of Kaduna state, the site chosen is considered a rural area. According to Rogers (2008), dairy farms should be located in rural zones, away from residential dwellings, schools or hospitals. As well, SAI

Platform Dairy Working Group (2009) opines that the locality should as well consider proximity to urban centres for economic reasons.

ii. *Land Use:* the site chosen is surrounded by other similar industrial agriculture developments like poultry farms and fisheries farm. In a report by Agriculture and Resource Management Council of Australia and New Zealand (1999), siting for dairy farms should be located amidst area zoned for industrial agriculture purpose.

iii. *Infrastructural Amenities:* infrastructural utilities like electricity, road network, pipe borne water and cell reception are considered in choosing the site for the dairy farm design development. Bickert *et al*. (2000) opines that a year-round supply of electricity and pipe borne water is very important for the smooth running of a dairy farm as a dairy farm is an electricity and water intensive farm development. Rogers (2008) says that a good road network connecting a dairy farm to the outer community is very crucial in supply and export in and out of the farm.

iv. *Consideration for Sensitive Area:* the site chosen has no proximity to any area demarked as sensitive area in terms of radiation, threatened species habitat of endangered fauna and flora or have any history of a toxic activity ever taken place on the site as dairy farms is crowned a very sensitive farming operation. According to Agriculture and Resource Management Council of Australia and New Zealand (1999), dairy farms should be located away from areas marked as sensitive area.

v. *Topography:* the site selection considers terrain as the location of buildings on the site has an appreciable dependence on site elevation considering waste generating facilities, runoff and rainwater management. Bickert *et al*. (2000) opines that site slope in dairy farms design is an important consideration in designing how runoff could be diverted away from the facilities, livestock yards and traffic areas.

vi. *Land Size:* expanse of land is also another consideration. A geographic location with sufficient land size is considered in selecting the site. Bickert *et al*. (2000) opines that a dairy farm development should take into account land large enough to effectively cater for the facilities, effluent and solid wastes/sludges produced at all stages of the process (i.e raw, post treatment, post storage e.t.c). And land large enough to bear parking spaces for both employees and visitors and service people.

vii. *Soil Type:* soil type that could easily support vegetation plantation at the same time structurally stable in carrying the load of the buildings and activities on the farm is also considered. According to Agriculture and Resource Management Council of Australia and New Zealand (1999), soil type is an important consideration in siting a new dairy farm development.

viii. *Security:* to promote safety against cattle rustling, the location is considered to have an appreciable consideration for security. Okoli and Okpaleke (2014) recommends that security should be accorded significant consideration owing to the menace of cattle rustling around flash point, one of which is Kaduna state.

The site selection follows the result gotten from a comparative evaluation of two viable site options base on the selection criteria established on *section 5.2.* The evaluation is done by awarding scores using a range of 0 – 3, as follows: 3 = high, 2 = medium, 1 = low, 0 = poor.

Both sites are generally located at rigachikun area of Kaduna state. Plate shows the respective sites in consideration. Plate XXVIII and plate XXIX show the site on google earth.



Plate XXVIII: Site A

Source:Google Earth (2015)



Plate XXIX: Site B

Source: Google Earth (2015)

From the above viable choices for site to locate the dairy farm development, table 6.1 evaluate the sites. From the evaluation results, site B is chosen, having the highest point score of 21-points out of 24-points.

Table 6.1: Site Evaluation Using Selection Criteria

Selection Criteria	Site A	Site B	Remarks
Locality	3	3	Both sites are located in rural areas close to urban area.
Land Use (Neighbohood)	3	3	Both sites are within a neighbohood of industrial agricultural developments.
Infrastructural Amenities	2	2	Both sites have access to electricity, road network, and cell reception. But no pipe borne water.
Consideration for Sensitive Area	3	3	Both locations are not tagged sensitive areas, neither are they close to sensitive areas.
Topography	1	3	Site A is relatively flat, while site B slopes to the rear side of the site.
Land Size	2	3	Site B is larger than site A
Soil Type	3	3	Both sites have soils suitable for livestock farming.
Security	3	3	Both sites are surrounded by similar developments and well secured.
Cumulative Score	*20*	*23*	*Points Out of 24*

KEY: 3-HIGH 2-AVERAGE 1-LOW 0-ABSENT

6.2.2 The Site

The site is located at 10°43'15.57N 7°20'26.72 at 2108ft elevation along the sabon birni-dogon dawa airport road in Rigachikun local government area of Kaduna state. The site is surrounded by mostly other industrial agricultural facilities and bare farmlands. The site is enriched with amenities as electricity grids, access tarred roads leading out of the locality and GSM. The site is about 118764.98sqm with relatively flat surface with the highest altitude of 647 above sea level and lowest of 642. Figure 6.1 shows the site selection.

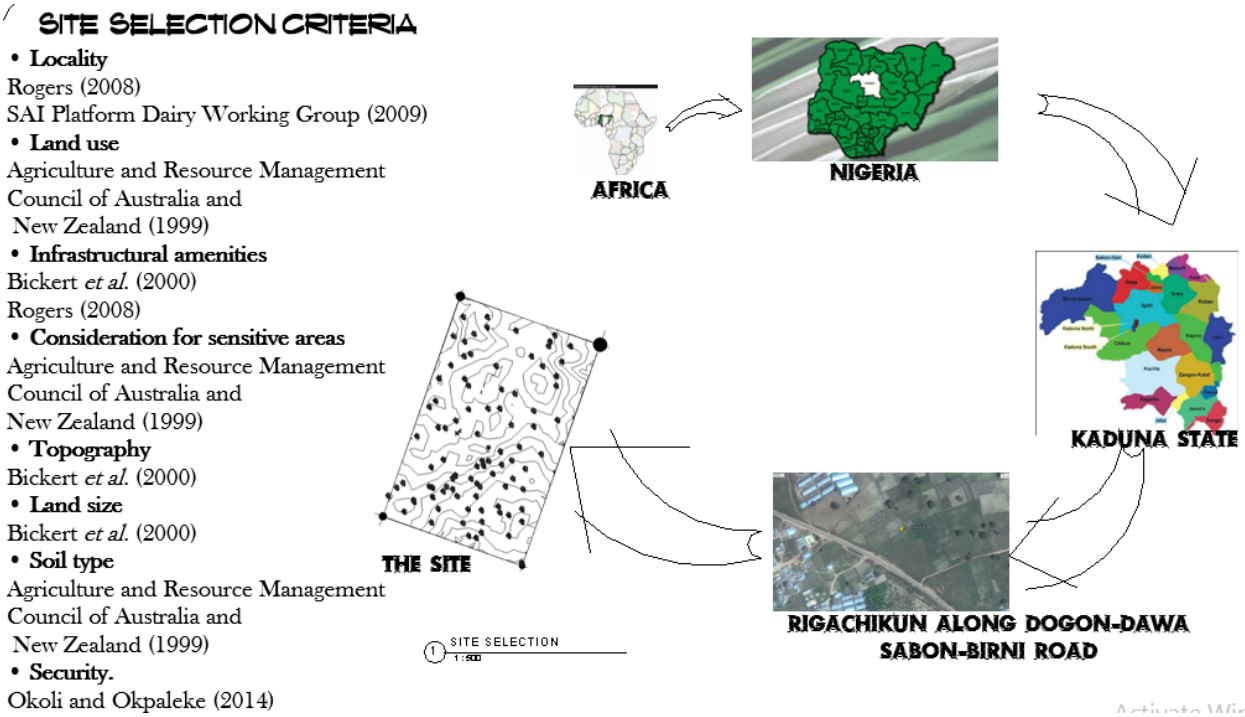


Figure 6.1: Site Selection

Source: Researcher's Sketch (2016)

6.3 Site Analysis

The site is analysed based on themes that have significant bearing on the consequent design to be proposed. The themes under which the analysis is made are accessibility and site

surroundings to give an informed justification on why functions and activities are located at a designed location. Vegetation and topography to highlight the nature of the site give a natural guide on how to adequately design with the nature of the site. And finally micro climate analysis which presents the climatic peculiarities of the site and give a base for making design decisions that should suite the site climatic features. Figure 6.2 shows the overall graphic analysis of the site.

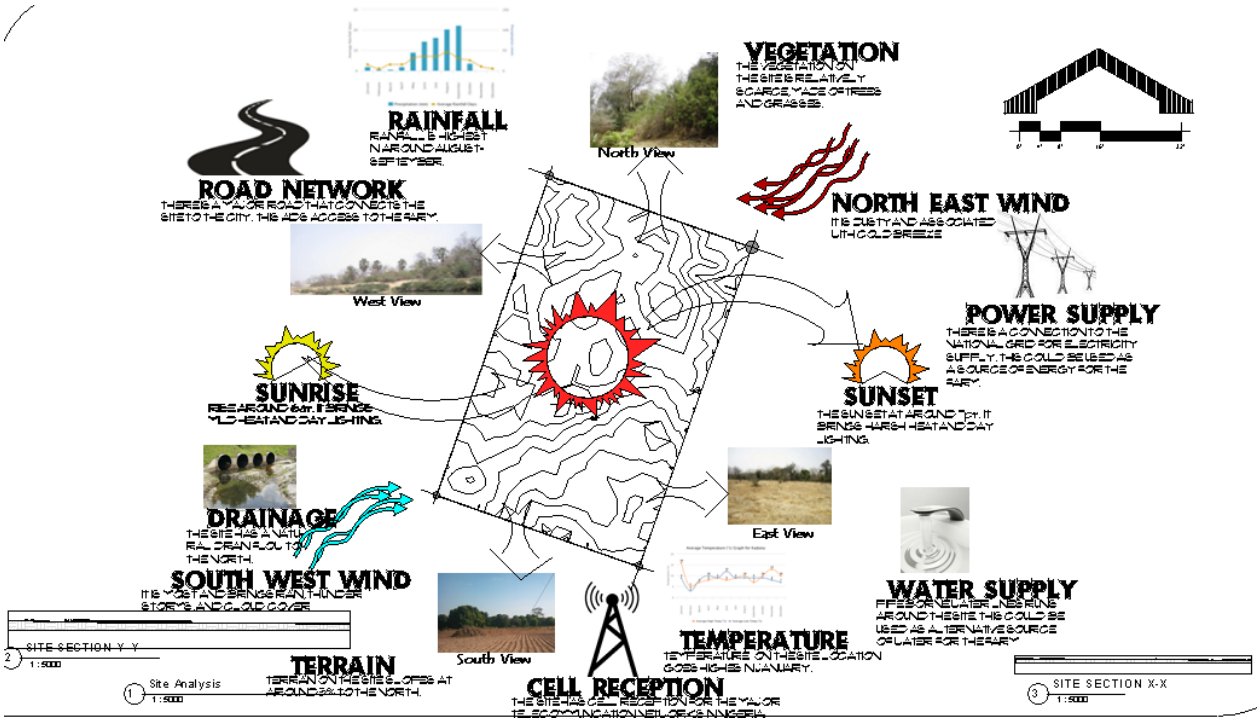


Figure 6.2: Site Analysis

Source: Researcher's Sketch (2016)

6.3.1 Accessibility and Site Surroundings

The site is a vast land, currently used as a farm land. It is however surrounded by farmland from north, south, east and west. The site has an accessibility point from the major road of dogon-dawa sabon-birni road.

The site is also blessed with infrastructural amenities in form of connection to the national grid of electricity power supply, pipe borne water, tarred road network connecting it to the main town and also connected to the globe through cell reception.

6.3.2 Vegetation and Topography

The vegetation on the site is relatively scarce with mostly grasses and a few trees. Topography of the site however slope to the north. Figure 6.2 shows a graphic illustration of the analysis.

6.3.3 Micro-Climate Analysis

The north east wind comes along with dust and brings along harmattan while the south west wind come along moist and bring along rain and thunder storms. The rainfall on the site generally is more prevalent around the months of August to September. And temperature on the site is high at around the months of January.

6.3.4 S.W.O.T Analysis on Site

From the analysis data presented on *section 6.3.1 to 6.3.3,* figure 6.3 shows graphically SWOT analysis conducted as a resolve from the analysis data presented.

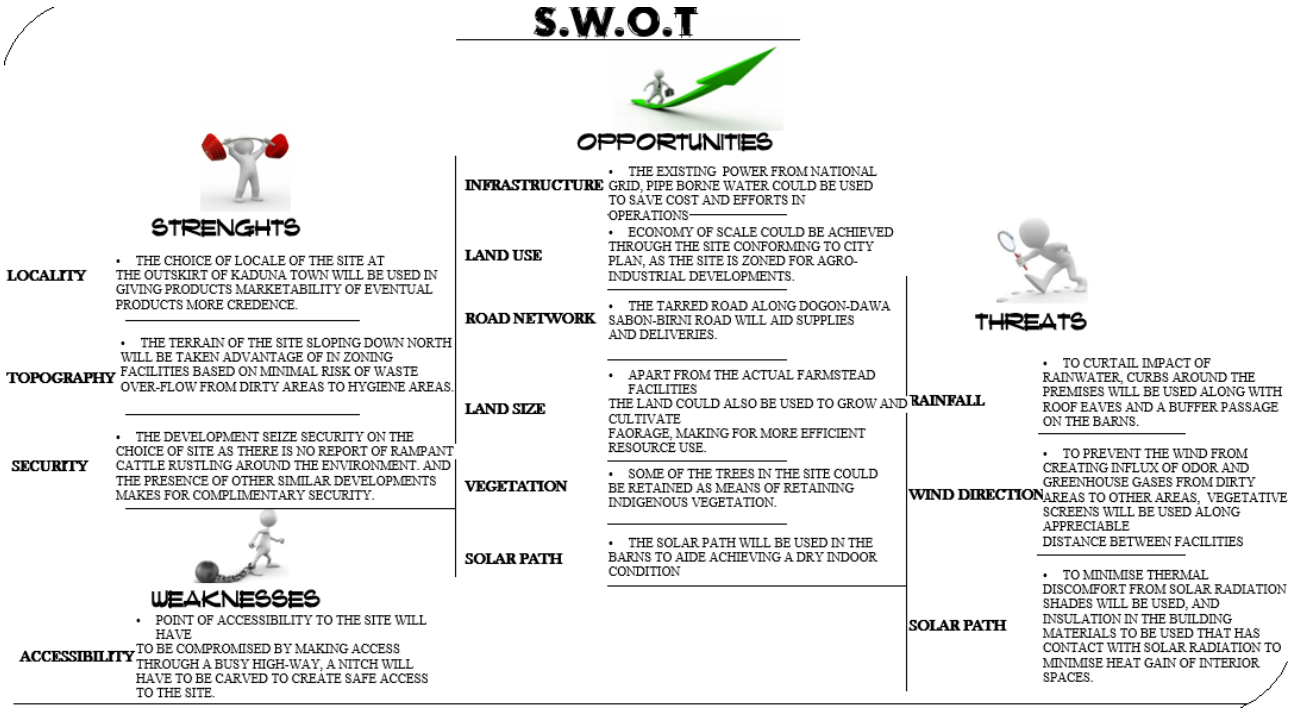


Figure 6.3: Site SWOT Analysis

Source: Researcher's Sketch (2016)

6.4 Brief Development

This section thus establish a breakdown of conceived needed facilities for the proposed model dairy farm Kaduna with considerations for state of the art operations and the synthesized requirement for the design of functions, farm premises and the inherent space requirements for each function. The section takes a step more in presenting a guide for standards in sizes of spaces required to accommodate considered activities the spaces are conceived to cater for.

6.4.1 Space Schedule/Design Guide

Looking at the nature of the spaces making up a dairy farm, some spaces like barns requires a valid idea of a typical cattle body size to establish adequate size for a cattle barn (figure 6.4). Spaces like processing area, machine room, milk centre and feed centre

requires machines, *Appendix D* shows the machines needed for the spaces with an idea for their respective sizes; while others like admin block follows the normal consideration for anthropometrics. Space schedule is established using space guides from space requirements of the cattle, machines and anthropometrics respectively *(Appendix E)*

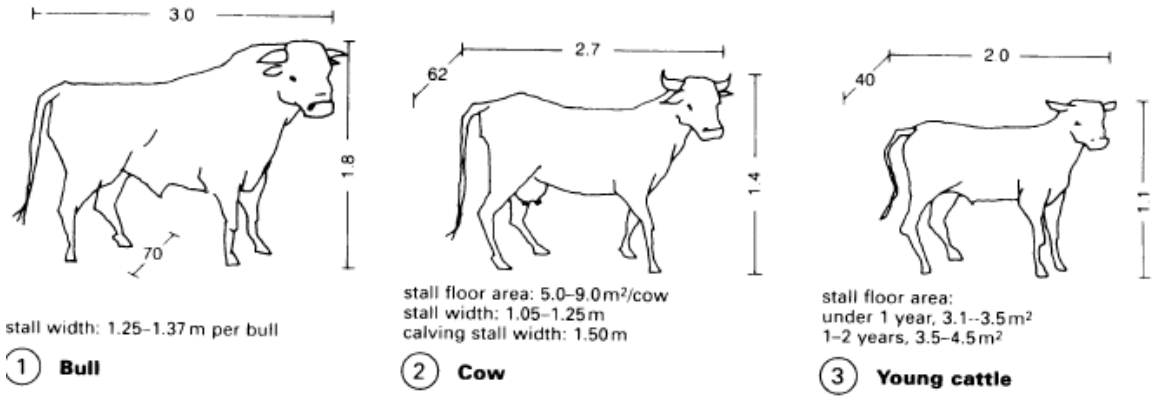


Figure 6.4: Cattle Anthropometrics

Source: Neufert and Neufert (2012)

6.5 Concept Development

Concept formulation in architecture lends logical, symbolic, ideological or iconic guide to design as an enriched and meaningful product oriented endeavour in achieving visual appeal and functional performance.

Owing to the goal of the proposed design of producing a design that is environmentally responsive and a design that enliven the occupants in the course of contributing to sustainable development, the concept used in the design is pragmatic approach (form follows function). The concept is derived from relationship matrix, spatial flow diagram and zoning.

6.5.1 Relationship Matrix

The relationship matrix is established using the components of the dairy farm design to measure the strength of interconnectivity of the functions to one another. Of note however, is the functions with very strong relationship and those with the very weak relationship. The functions with very strong relationship are function that must be designed to have an unhindered access from one another, such relationship are those that exist between barns and waste treatment, barns and manure depots, manure depots and waste treatment plant, processing plant and milk centre, and processing plant and the admin block. Functions however that has very weak relationship are processing plant to manure depot, waste treatment and milk centre, and feed centre to waste treatment. Figure 6.5 elucidate graphically the relationships between the respective dairy farm components.

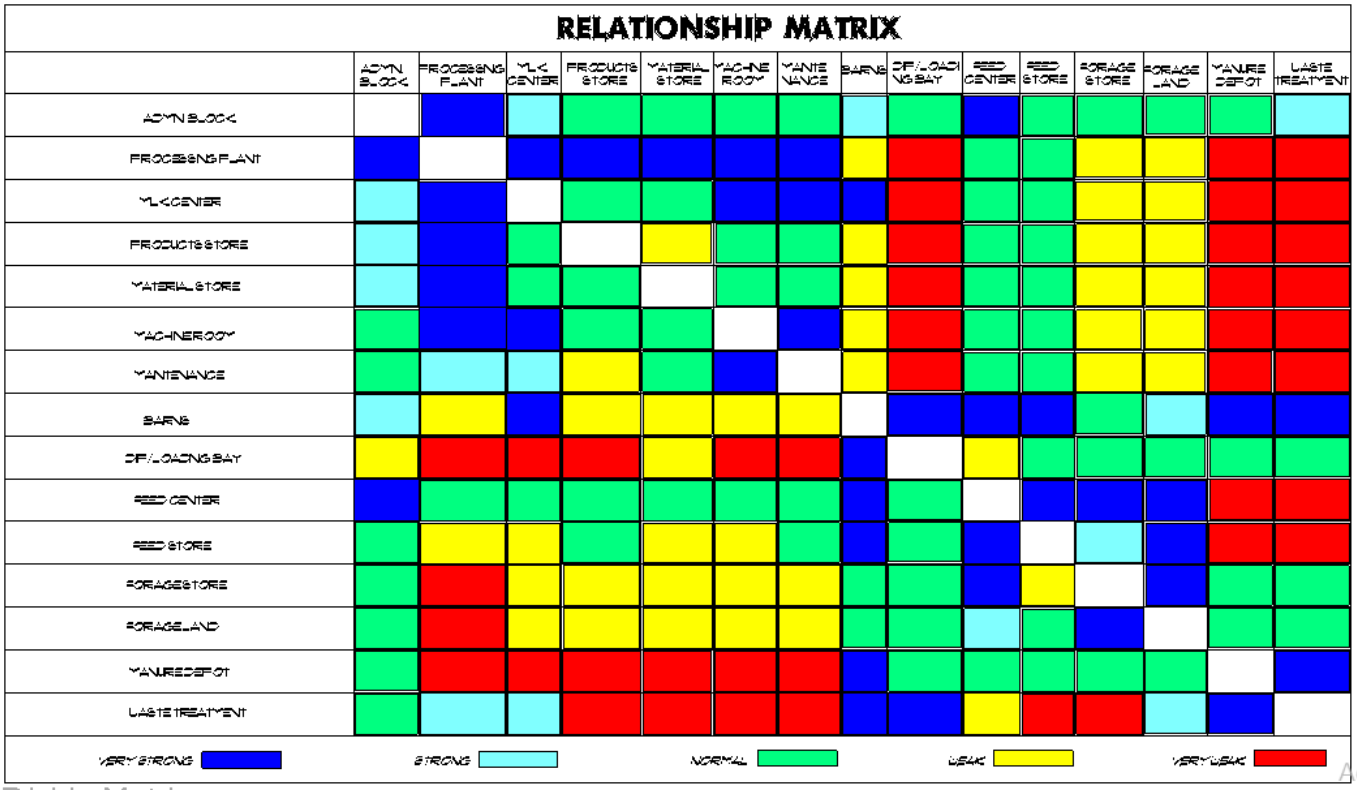


Figure 6.5: Relationship Matrix

Source: Researcher's Sketch (2016)

6.5.2 Spatial Flow

The spatial flow demonstrate interconnectivity of sections based on the relationship that exist between the sections. This flow forms part of the concept development. Figure 6.6 show the spatial flow diagram.

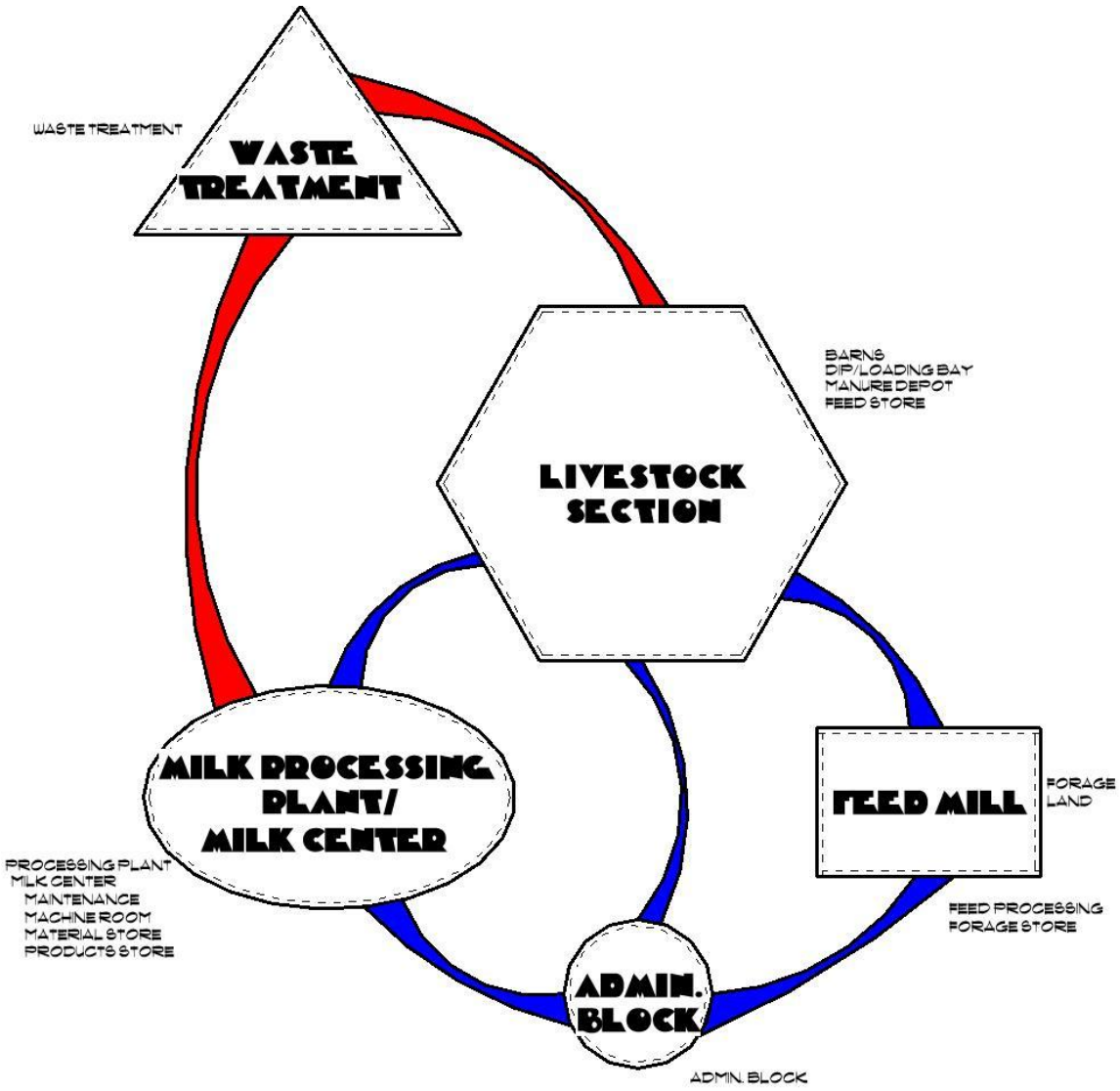


Figure 6.6: Spatial Flow Diagram

Source: Researcher's Sketch (2016)

6.5.3 Zoning

The zoning is based on the relationship matrix and spatial flow along the site topographical nature discussed on *section 6.3.* The zoning categorise functions based on terrain and level of hygiene requirement. Figure 6.7 graphically illustrates the zoning

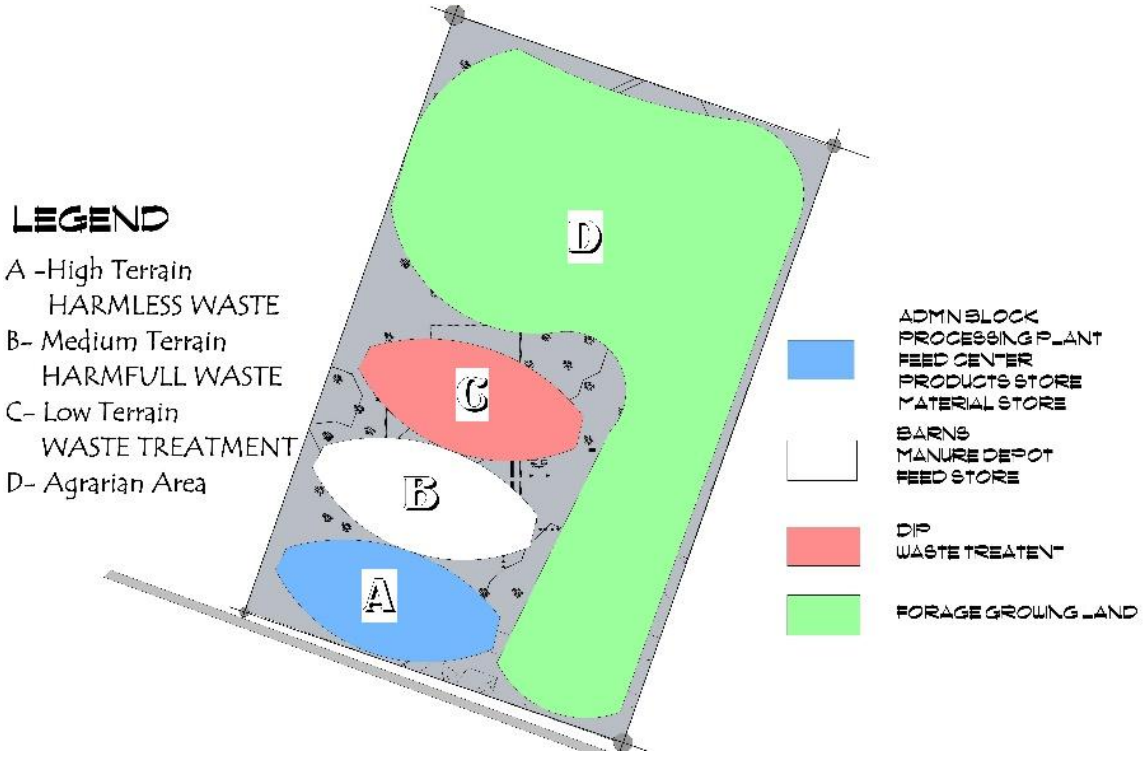


Figure 6.7: Site Zoning

Source: Researcher's Sketch (2016)

6.6 Application of "The Holistic Design Framework for Achieving Sustainable Waste Management on Dairy Farms" On the Proposed Model Dairy Farm, Kaduna

The framework evolved on *section 5.3*is applied in demonstrating the proposed design of Model Dairy Farm, Kaduna. This section presents the step-by-step application of the framework while also serving as a design report. The design merge the philosophy of cluster farm design with disperse farm design to achieve the functionality and good inter-

functions relationship a cluster design offers and also the disperse design to achieve compartmentalization of functions and activities. The design of the livestock section adopts loose housing approach, with races as means of controlled flow and circulation. Generally, the farm is designed to give no consideration for a waste output: the design aimed at achieving a semi eco-industrial park where wastes from processing facilities and livestock section becomes the raw materials to the composting facility and waste water treatment plant in producing compost and irrigation water for farmers and other landscape personnel (see figure 6.8). Also, *Appendix E*shows the complete set of presentation drawings.

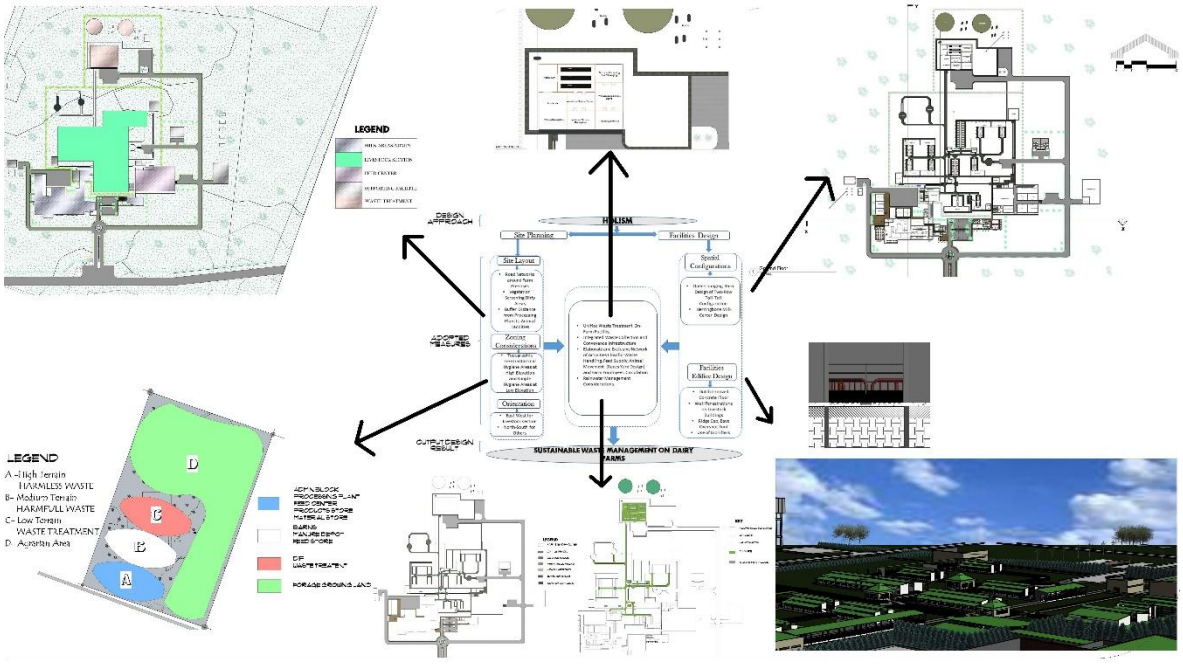


Figure 6.8: Application of Framework

Source: Researcher's Sketch (2016)

6.6.1 Site Planning

While achieving the needed functional relationship between functions on the site, the design of the farm also establish an elaborate flow of process for waste collection and

conveyance, feed supply and conveyance, employees' circulation and accessibility from the different sections of the farm and also a clear boundary between unrelated functions. The site planning is also designed to control accessibility for different categories of farm customers.

To complement the general farm access security muster point in promotingfarm security, the farm house meant for an indigenous family from the locality to serve as security personnel is strategically located where the obviously prone target for security breach is high i.e the cattle area. In aiding the ease of operation of the farm, feed storage are strategically placed to serve some barn categories. Farm ancillaries comprising of the dip, crushes and loading bay is designed to be located within the livestock section, thereby making for good functionality.Figure 6.9 shows the site plan.

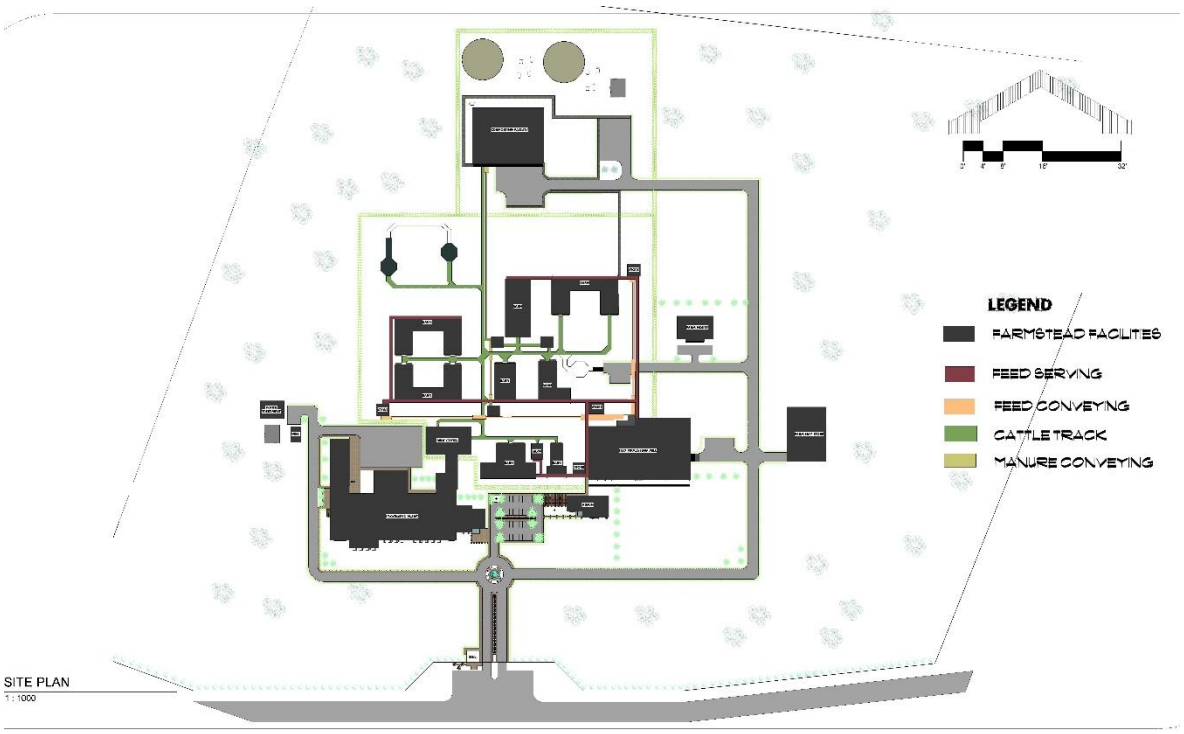


Figure 6.9: Proposed Site Plan

Source: Researcher's Sketch (2016)

6.6.1.1 Site Layout

The site layout is designed to afford the farm an elaborate road networks as it promotes the course of supply and deliveries from and out of the farm. Vegetation is also used in creating compartment of general facility as a unit securing the integrity of the activities inherent in the facility while creating visual screen from other facilities as well as a means for capturing as much greenhouse gasses as possible. Also, the layout design ensures sufficient buffer distance of about 25m from the admin side of the processing plant to the first contact point to livestock area.

6.6.1.2 Site Zoning

Using topographical terrain, incentive zoning is adopted. Three zones were eventually established, namely: high terrain and harmless waste zone, medium terrain and harmful waste zone and low terrain and waste treatment zone. Figure show the graphic design of site zoning (see figure 6.7).

6.6.1.3 Orientation

The livestock areas of the farm are designed to make the wider sides face east and west to seize positive advantage of the sun and wind movement in ensuring a dry indoor of the interior spaces of the livestock section. While for other facilities, the wider sides are designed to face north and south to avoid solar heat gain and discomfort to inhabitants. The site plan on figure shows the orientation (see figure 6.9).

6.6.2 Facilities Design

The buildings generally are designed with the sole aim of achieving sustainable waste management. Such, keen concern is duly accorded to the spatial design of functions that aids the process of waste management; enveloping design using flooring, walls and roof design are used as elements in achieving sustainable waste management.

6.6.2.1 Spatial Design

The spatial design of the respective functions are made to make for ease in waste management. Of special note are the barns design and the milk centre design. The barn design adopts the two-row tail-to-tail configuration with an alley in between lying areas. While the milk centre adopts a herringbone system where the pit has wash water collection point and other sides for cattle milking are also easy to manage. Figure 6.10 shows the floor plan showing all functions.

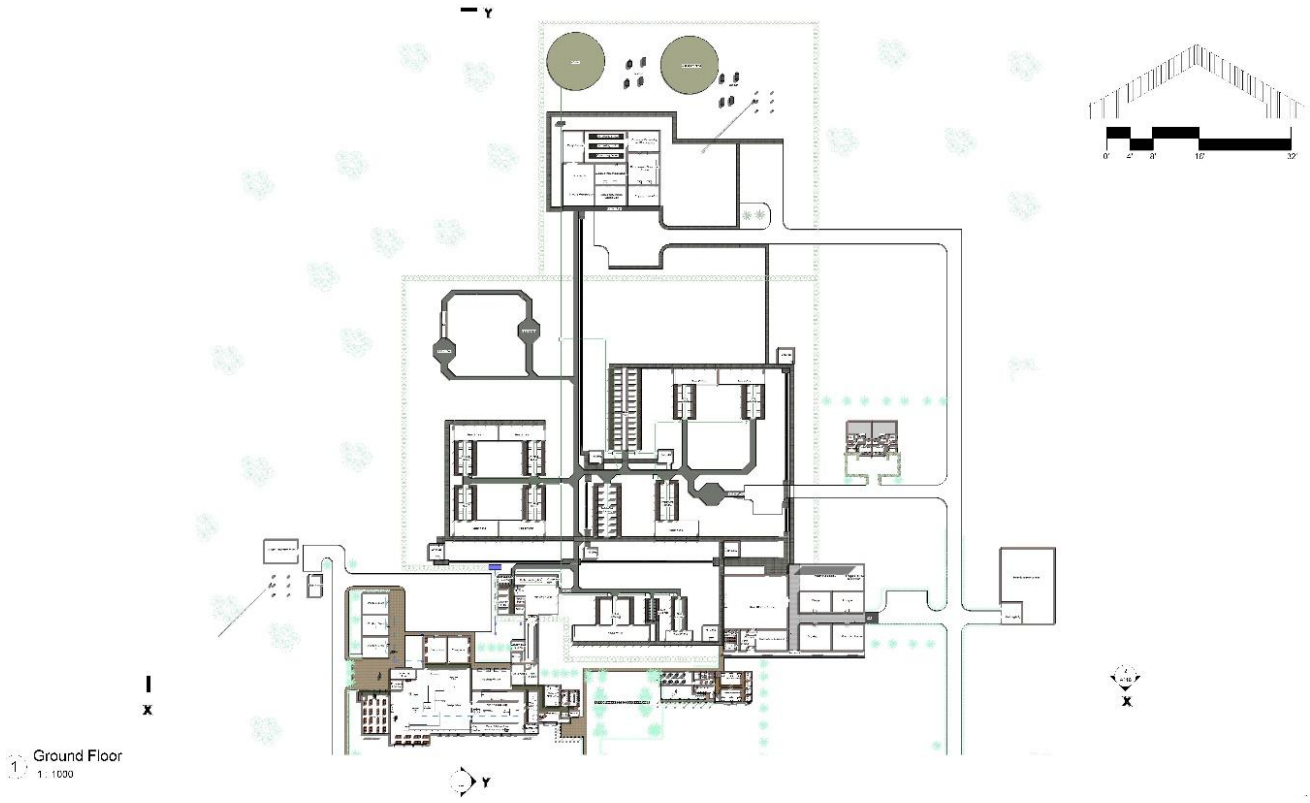


Figure 6.10: Proposed Ground Floor Plan

Source: Researcher's Sketch (2016)

The design creates a unit out of the processing plant, milk centre and allied spaces and functions that aids the activity of processing and harvesting of milk from the cattle. The processing plant is designed with a central gutter system for wash water collection and conveyance. The gutter follows the production line from which possible spills and the need for washing is high. Figure 6.11show the plan of this unit.

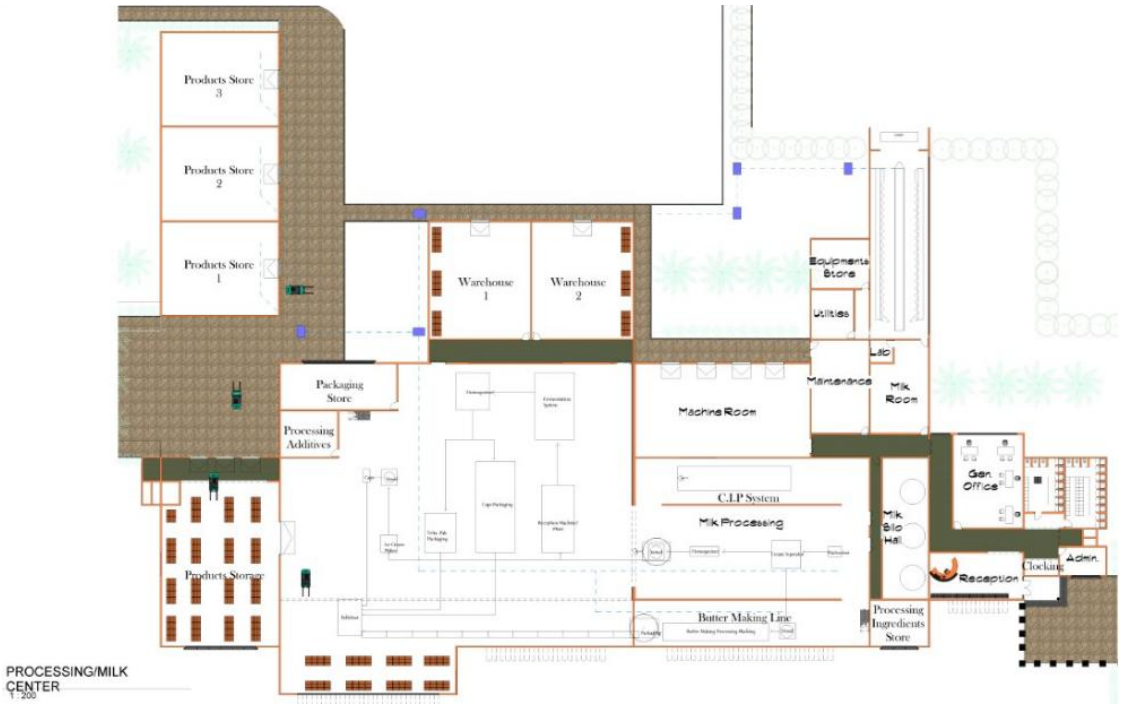


Figure 6.11: Proposed Plan, Milk Processing Plant

Source: Researcher's Sketch (2016)

Barns are designed as a cluster adopting consideration for transition cow welfare and need along the bulls and calf's consideration also for welfare and environmental need. The barns are generally designed to be a two-row housing with a feeding yard attached where feed and water troughs are located. The barn design uses a central gutter system along the alley of the barns for effluent collection and conveyance. The alley design also proffers measure for manure collection and evacuation using the scrape method. Figure 6.12 shows the plan of the barns.

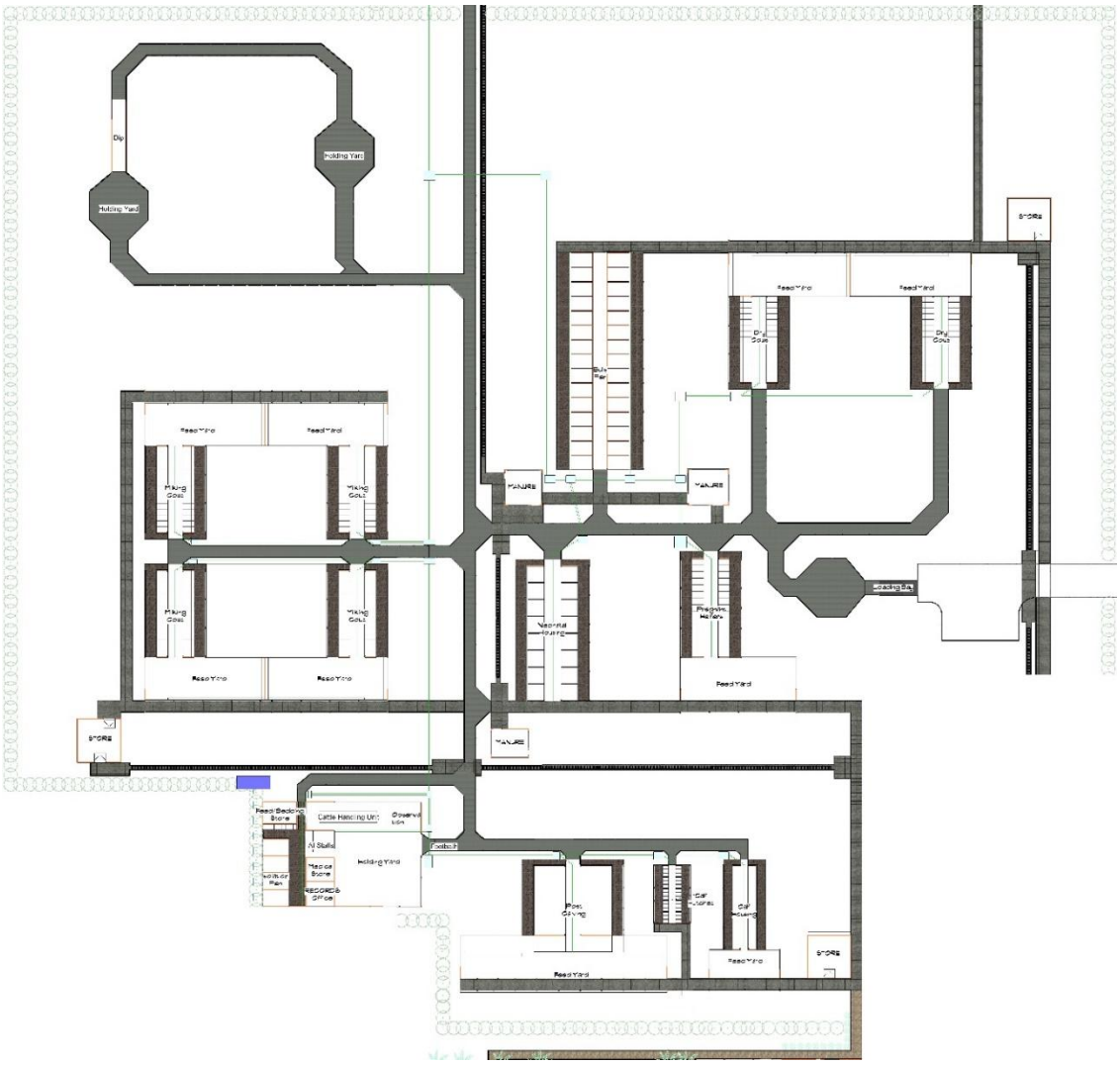


Figure 6.12: Proposed Plan, Livestock Section

Source: Researcher's Sketch (2016)

The feed centre is designed to have different storage units for the different feed nature required by the cattle. Also, supplements store is provided for preserving those supplements that requires different storage environment. The design makes machine area easily accessible from other feed stores for processing and mixing. While the bulk feed storage of processed feed and rations is design with consideration for cattle dieticians'

office to supervise distribution to the respective barn sections is made attached to the storage space and also for records keeping. Figure 6.13shows the plan of the feed centre.

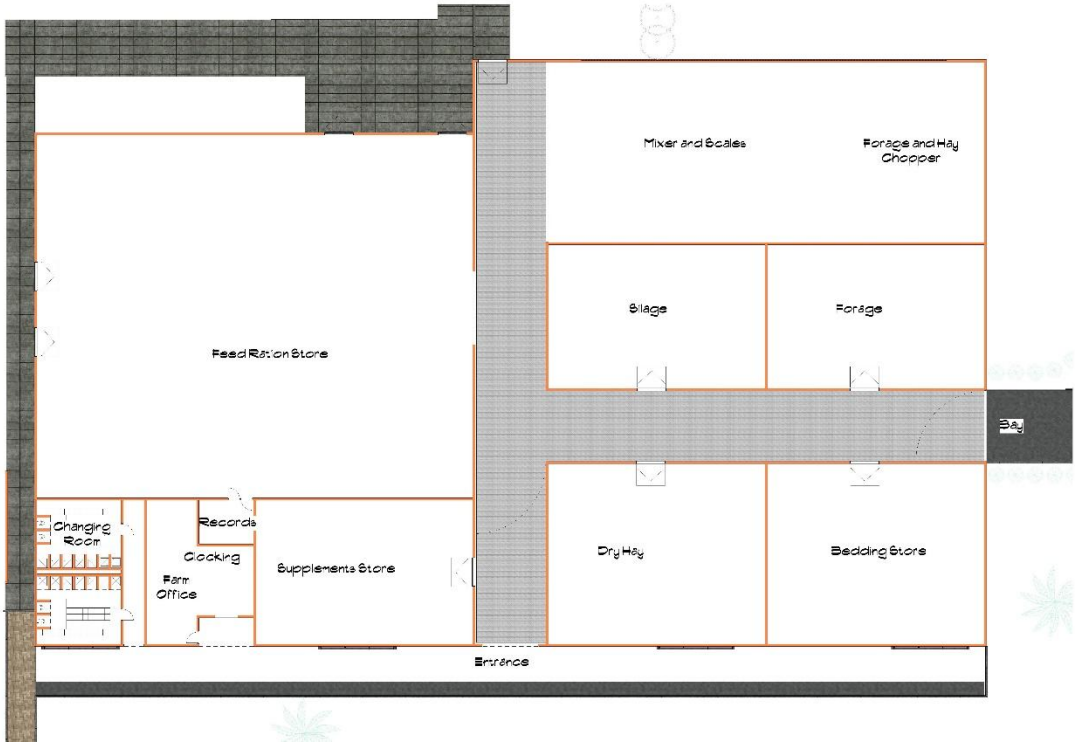


Figure 6.13: Proposed Plan, Feed Centre

Source: Researcher's Sketch (2016)

The admin block is designed to make for a psychological differentiation in category of livestock workers, dairy processing workers and administrative personnel. The compartmentalization is achieved through the creation of access from the livestock area to the office spaces for that category of employees. Reception is designed to serve the whole employees making for a general waiting area. Attached also is a cafeteria with an outdoor eating space that could also serve as break and socialization spot. Figure 6.14shows the plan of the admin block



Figure 6.14: Proposed Plan, Admin and Farm House

Source: Researcher's Sketch (2016)

6.6.2.2 Use of Enveloping Design Elements

In promoting the course of sustainable waste management, the roof used on the design generally is shed roof, thereby avoiding complexity. Of special note is the roofing design used on the barns: aside the shed nature of the roof, ridge gap opening of 500mm is used along eaves overshot of 750mm. These are done to enhance the indoor quality of the barn interiors by affording the design better air exchange. Figure 6.15shows a section revealing the roof design.

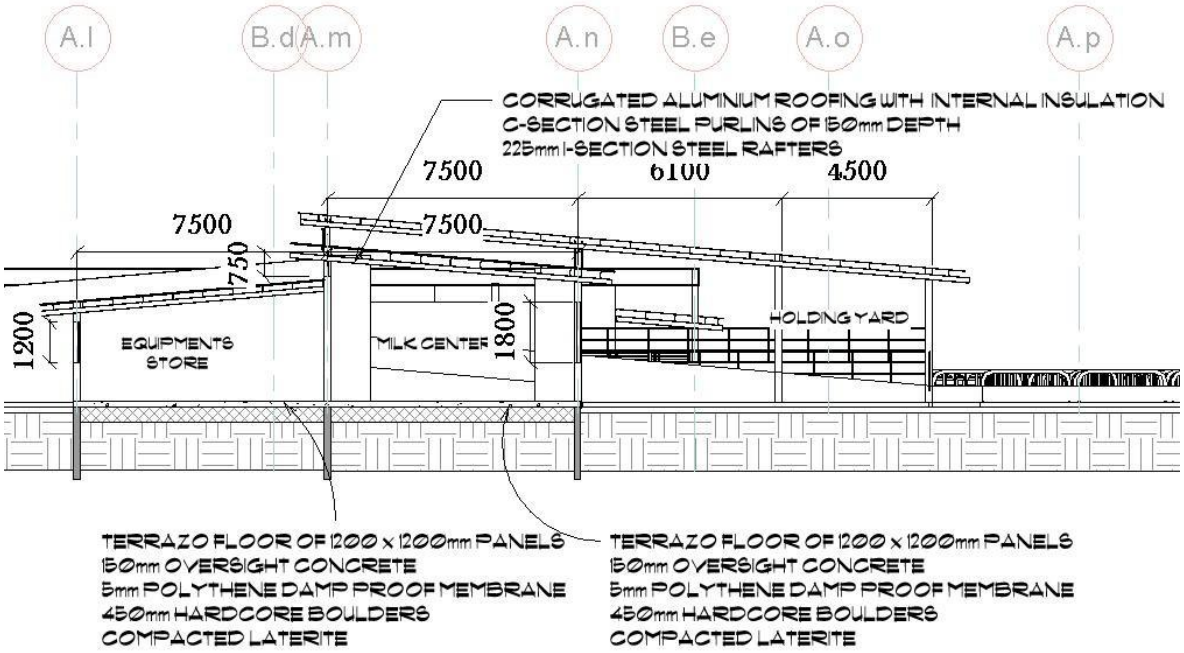


Figure 6.15: Proposed Section Y-Y of Livestock

Source: Researcher's Sketch (2016)

The walling design used on the farm creates absolute shelter for the respective inhabitants while considering the peculiar need of the space and activities carried out within the space. Of note also is the barns: the walling are designed in a combination of dwarf walls of 1500mm, open height walls and built height walls of about 3500mm with steel pipe demarcations. As aimed, the design achieve a confined space at the same time providing the level of openness needed (see Plate XXX).

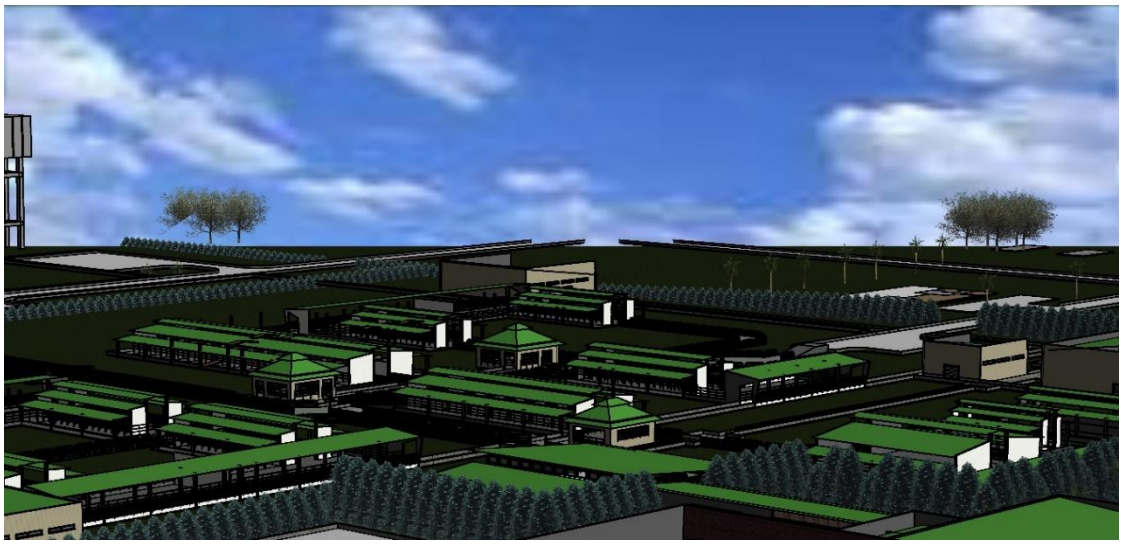


Plate XXX: Proposed Section, Livestock Section

Source: Researcher's Sketch (2016)

Flooring design used on the farm is specific in nature based upon the peculiarities of a functional space. Of special note is the flooring design used on the barns: dutch-grooved design made of concrete is adopted to aid the course of sustainable waste management as well as functionality.

6.6.3 Integrated Design Considerations

Generally, the farm is designed to provide possibility for easyobservation and movement for the various activities on the farm. This is done through unifying waste treatment facility with accesses of circulation, making handling lanes thatpromote smooth cow traffic flowwith maximum safety for handlersand cattle,convenient feeding and bedding conveyance, and also vehicularaccess around farm premises.

The unified waste treatment comprise of a manure composting facility and an effluent treatment plant. The composting facility is designed to contain the manure to be treated adequately without any unwarranted spills to the surrounding environment thereby

affording the facility control on the waste. The process of the composting starts from reception to the production of packaged manure compost for supply. While effluent treatment treats wastewater, wash water and effluent from the farm facilities. Figure 6.16 shows the plan of the treatment facility.

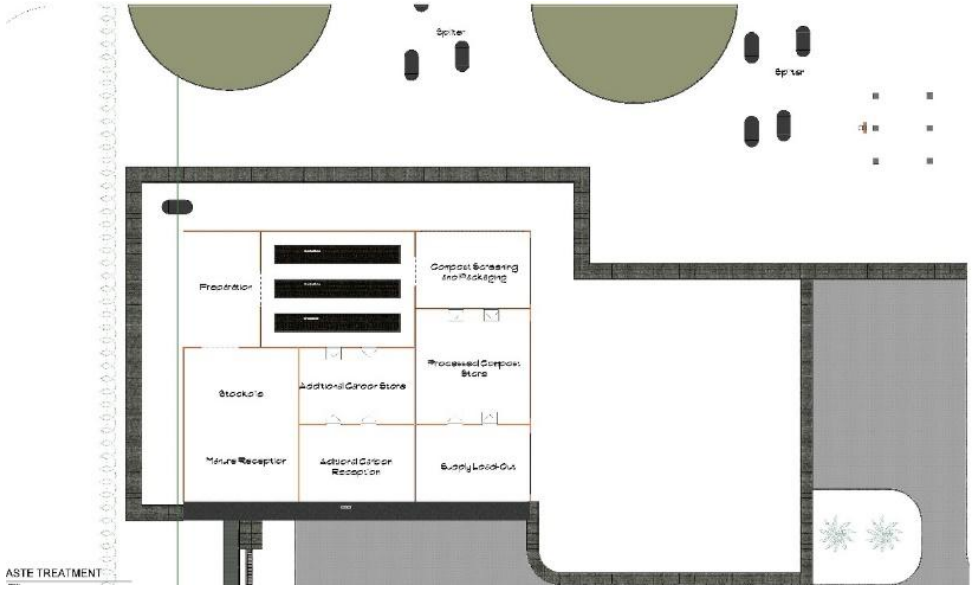


Figure 6.16: Proposed Plan, Waste Treatment

Source: Researcher's Sketch (2016)

Waste collection and conveyance infrastructure is integrated in the design through the use of central gutters within farm facilities for the collection and conveyance of wash water and effluent: the use of races around farm premises for handling manure, temporary manure depot and a conveyor system for transporting manure to long distances.

Also, the design ensure a flow for each process/activity that is exclusive to that particular flow in terms of employee circulation specific to their work flow i.e those in the livestock section dealing with cattle exclusive to those in the processing plant. The races design also making for absolute control of cattle movement all around the farm. The process of waste

and feed carriage from producing facility up to treatment and stores respectively (see figure 6.17).

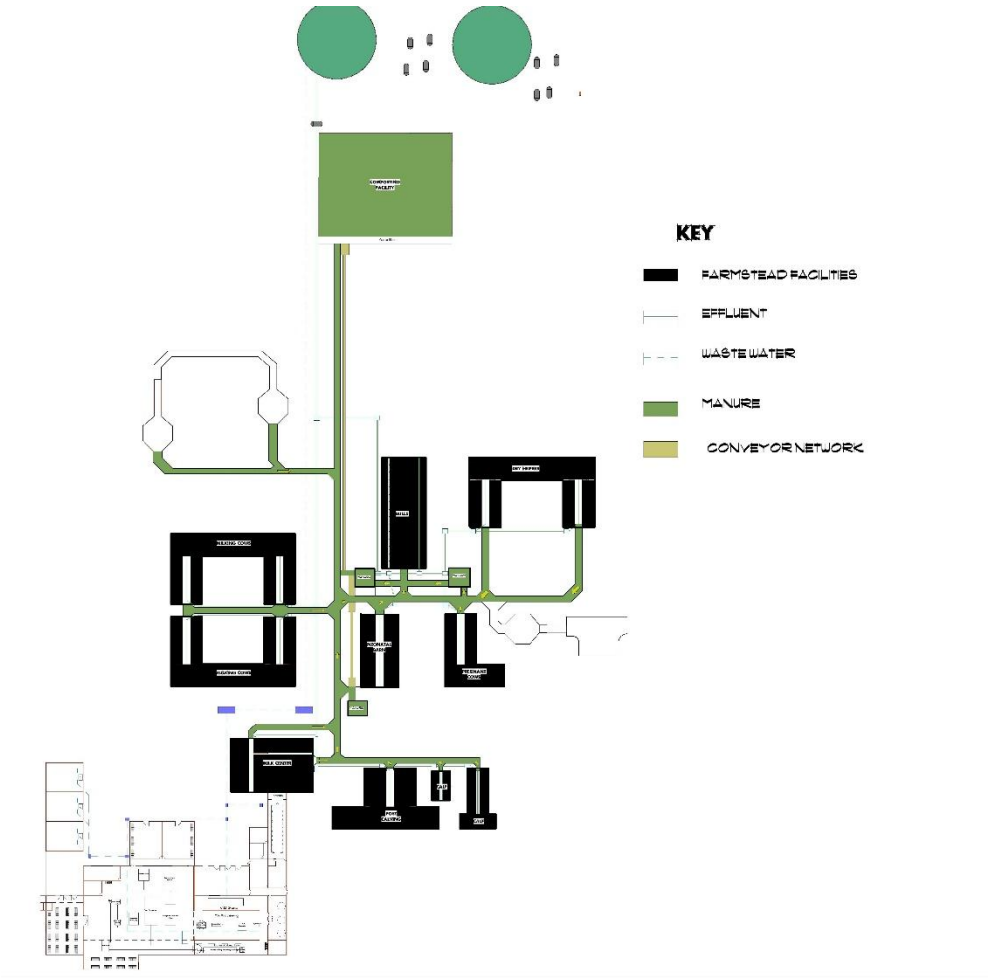


Figure 6.17: Proposed Schematic for Waste Flow

Source: Researcher's Sketch (2016)

To handle issues of rainwater, runoff around farm premises curbs are used around livestock section to ensure adequate waste containment and prevent rainwater influx. While terraces are used in barn designs to create buffer that is used to prevent driving rain from accessing barn interiors (see figure 6.9).

CHAPTER SEVEN

7.0SUMMARY AND CONCLUSION

This chapter ties the nuts linking up the entire work as a single endeavour with chapters and sections whose resolve is derived from a sequence of natural flow and outcome of preceding chapters and sections in achieving the research aim and objectives while proffering credible responses to research questions posed.

7.1 Summary

The design of dairy farms has waste management as one key area, looking at the nature and magnitude of these waste on cattle health, welfare and environmental implications. So far, dairy farm designs are not decisive in dealing with waste management at design stage. This is reported from literature reviewed from around the world, Nigeria inclusive. Regardless of the agricultural nature of dairy farms, neither agricultural engineers nor veterinarians are equip enough with sufficient requisite in design understanding to produce a dairy farm design that achieves nexus between infrastructural requirement of cattle breeding, cattle health and welfare with sustainable development ideals: designs remains the architects forte.

From literature, this research shows that sustainable waste management on dairy farms comprise of a three tier hierarchy of reducing waste generation, then establishing measure for effective evacuation and finally providing for sustainable waste treatment. The design approach to achieving this waste management is established to be through site planning design consideration, farmstead facilities design considerations for waste management and design measures and considerations for waste handling.

The research use pragmatic research philosophy that adopts the problem-oriented approach of functionalist research paradigm, the research is qualitative in design using case study strategy. Nagari Integrated Dairies Ltd, Keffi, Niyya Farms, Kaduna and Lamda Farms are selected through purposive sampling to serve as case studies. Data gathered from the cases covers site planning considerations for waste management, facilities enveloping design considerations and design measures and considerations for waste handling as independent variables using observation as gathering technique. Analytic induction is of template analysis is used to analyse data recorded according to the design considerations implemented through variables and strategies which is portrayed using narrative analysis.

From the data analysis, the result shows that out of the three independent variables, site planning considerations for waste management on dairy farms is the most implemented, followed by farmstead facilities design considerations for waste management and the least implemented, however, is the design measures and considerations for waste handling on dairy farms. Looking at the specific strategies, the result shows the need for waste treatment facility, considerations for integrated drainages/rainwater management, enhanced accessibility around and within farm facilities as the most crucial design needs. The need for a spatial design of farm from the site layout to the spatial design of unit facilities and the use of enveloping design elements on facilities is also established. And finally, the crucial need for zoning facilities base on similar waste generation and the use of vegetation around farm premises.

Using the design flaws established, a framework referred to as “Holistic Design Framework for Enhancing Sustainable Waste Management on Dairy Farms” is developed to serve as guide in the design of a dairy farm with sustainable waste management process.

And finally the framework is used in demonstrating a design of a Model Dairy Farm, Kaduna.

7.2 Conclusion

In conclusion, the aim of the research is achieved through assessing existing design measures and considerations with regards to their effectiveness in addressing waste management issues on dairy farms in northern Nigeria. This is done by achieving the research objectives. The first objective (to investigate design strategies for waste management on dairy farms in northern Nigeria) is achieved by establishing a base for design strategies to be investigated on *chapter two,* this results in data presented on *chapter four.* The second objective (to interrogate the impacts of such design strategies for waste management on dairy farming in northern Nigeria) is achieved through assessing the impact of the implemented strategies on the effectiveness and wholesomeness of waste management process on the case farms on *section 5.2.* The third objective (to develop a design framework for enhancing sustainable waste management for large scale dairy farms design) is achieved using guide from *chapter two* and the resolve on *section 5.2* to evolve a design framework on *section 5.3.* The last objective (to demonstrate the applicability of this framework in the design of a model dairy farm in Kaduna) is achieved on *chapter six* to propose a design demonstration of a Model Dairy Farm, Kaduna.

7.3 Recommendations

Born out of the rigor of the research as an endeavour, the following are hereby recommended:

1. Design strategies for handling waste on any waste generating complex should be given paramount priority by the designer to achieve a functional design that offers wholesome waste management.
2. Waste generating agro-industrial complexes like dairy farms should be adequately studied and assessed before construction in order to achieve a better design that supports sustainable development.
3. As the design of an industrial complex is diverse and requires multi-disciplinary inputs from other professionals in achieving not only fancy buildings forms and expressions, but a functional design that promotes environmental quality and ensure welfare of building occupants, architects should seek to properly harmonise credible inputs and guides from other professionals through holistic design approach in their designs in order to promote sustainable develop through wholesome waste management on industrial complexes.
4. The designs of agro-industrial complexes like dairy farms should be conceived to conceptualise the idea of a semi eco-industrial park in promoting efficient use of resources and higher profit margin while promoting sustainable development.
5. Elements referred to as Integrated Design Considerations for Waste Management on Dairy Farms (unified waste treatment facility; integrated waste collection and conveyance infrastructure; elaborated and exclusive network of activities flow for waste handling, feed supply, cattle movement and employees circulation; and

rainwater management considerations) should be well incorporated on the designs of new dairy farms or could be used to improve existing dairy farms complex.

6. In the design of a dairy farm, adequate attention should be accorded to layout design, incentive zoning using topography and similar waste generating facilities or complementary facilities base on functionality, and proper north-south and east-west orientation. And also, the edifies design should be ensured to adopt spatial design or configuration that aid the practice of waste management, and also the use of floor, walls and roofs as design elements in promoting wholesome waste management on dairy farms.
7. Government agencies and planning authorities should be more vigilant in supervision from design and construction stage of waste generating complexes to the operational stage of the complexes in ensuring strict adherence to the gospel of sustainable development.
8. The institute of architectural professionals should also organise more forum and seminars in instilling in their member adequate knowledge of contemporary issues of sustainable development and motivate them to imbibe a problem-solving approach suiting sustainable development in their designs.
9. Also, architects producing universities and polytechniques should incorporate more drills for sustainable designs in their curricula and in the design modules they give their students.
10. Agriculturist, veterinarians and investors in the agro-industrial sector should realise the relevance of consulting architectural professionals for their agricultural building designs.

7.4 Contributions to Knowledge

The following are the original contributions this research makes to knowledge:

I. Assessment that established specifics in site planning, farmstead facilities design and measures for effective and wholesome waste management on dairy farms in Nigeria.

II. Development of a design framework referred to as “Holistic Design Framework for Enhancing Sustainable Waste Management on Dairy Farms” to serve as guide for designing a dairy farm that is oriented at promoting sustainable development through waste management, functionality, productivity, animal welfare and social needs.

III. A demonstration using architectural design through holistic design strategies to achieve sustainable waste management on dairy farms in Nigeria.

7.5 Research Limitations

The limitations faced by the research were two-pronged.The first, being security situation of the country and the second being technical expertise and time frame. The security situation of the country lead to two request for case studies to be turned down. As the research also aimed at assessing the impact of design strategies used on dairy farms on cattle handlers and employees, the research was limited in expertise and tools for measuring quantitatively the amount of waste impact as well as the time period required to observe and study the employees.

7.6 Areas for Further Research

From the limitations of this research on *section 7.5,* there is the need for further research in assessing and establishing how design strategies impact on the employees on a dairy farm.

And a need for a comparative study on the impact of cattle housing welfare on milk yield productivity on dairy farms. Looking at contemporary trend on advancement in the agricultural industry and in promoting sustainable development through economic growth using tourism, the concept of agro-tourism is gaining significant appraisal. Further research should be done to explore how elements of tourism could be infused in the design of a dairy farm. As villages are fast advancing into cities and farm lands developing into residences and habitable building and looking at the ever growing need for food security and environmental protection, a research should look into how urban farming could safely be integrated into our cities while been mindful of the substantial potential for generated waste impact from the farm on the host city and on sustainable development. Also, as in the hotel star rating system and hospital bed number system, architectural ways of standardising dairy farms design base on scope of operations and advancement should be looked into with established standardised indicators of arriving at standards for qualifying a 50-cattle, 100-cattle, 200-cattle, 500-cattle e.t.c dairy farm.

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APPENDICES

AppendixA: *General Consent Form*

Department of Architecture, Ahmadu Bello University, Zaria.

Consent/ General Background

Hello,

Am Al'Ameen Ibraheem Bambale, an Msc student of architecture from Ahmadu Bello University, Zaria. Am conducting a research with title "*Assessment of Design Strategies for Enhancing Sustainable Waste Management on Dairy Farms*". The result from this study is assured to be used only for academic purpose.

General Information

Name of the farm:…….

Location:…….

Nature of Operation:……

Operation Schedule:…… Size of the Farm:……..

Capacity (Number of Cattle):…….

Number of Milking Cattle:……. Replacements:……. Dry Animals:……Breeds:……. Average Capacity of Industry (Milking):…….

Processed Goods:……

Facilities and Function

……

……

……

……

AppendixB: *Checklist for Case Study Observation*

S/N	VARIABLE	ABSENT	LOW	MEDIUM	HIGH	REMARK
	SITE PLANNING CONSIDERATIONS FOR WASTE MANAGEMENT					
1.	**Site Layout**					
a.	Road networks					
b.	Considerations for topographical features					
c.	Considerations for vegetation and buffers					
2.	**Orientation**					
a.	East-West barn orientation					
d.	North-South orientation for farm facilities					
3.	**Zoning**					
a.	Similar waste generating facilities location					
b.	Staff Facilities					
+	**FARMSTEAD FACILITIESDESIGN CONSIDERATIONS FOR WASTE MANAGEMENT**					
1.	**Spatial Design**					
a.	Barns					
b.	Milk center					
2.	**Enveloping Design Elements**					
a.	Floors					
b.	Walls					
c.	Roofs					
	DESIGN MEASURES AND CONSIDERATIONS FOR WASTE HANDLING					
a.	Accessibility (Alleys and Races)					
b.	Consideration for integrated drainage on farm premises					
c.	Interior drainages					
d.	Integration of waste management technology					
e.	Waste treatment facility					

	SPACE CAPACITY	UNIT AREA	MACHINERY/ FURNITURE	REFERENCES	MACHINE AREA	TOTAL AREA	CIR
	30 cattle	1.8sqm	None	Neufert and Neufert (2012) Mrema (2011)	None	30*1.8sqm =54sqm	50% =2
Y	15cow+15calves	1.8sqm+0.45sqm =2.25sqm	None	Mrema (2011)	None	30*2.25sqm =67.5sqm	50% =33
	15calves	0.45sqm	None	Graves *et al.* (2014)	None	15*0.45sqm =6.75sqm	50% o =3.
	15cows	1.8sqm	None	Mrema (2011)	None	15*1.8sqm =27sqm	50% o =13
	15Calves	0.45sqm	None	Mrema (2011)	None	15*0.45sqm =6.75sqm	50% o =3.
	1Bull	9sqm	None	Mrema (2011)	None	1*9sqm =9sqm	50% =4.
	24cows	9sqm	None	Powell and Lapworth (2006)	None	24*9sqm =216sqm	50% =1
	6cattle	9sqm	Scales Machine	Pickard (2002)	28.8sqm	6*9sqm+28.8sqm =82.8sqm	50% o =41
	24cows	1.8sqm	Herringbone Machine, Bulk Tank	Steinberg (201⁴alibaba.com (2016)	141.08sqm	141.08sqm	50% =70
	None	None	Proster Machine	Moran (2012) Mrema (2011)	87.36sqm	87.36sqm	50% =43
T	None	None	Milk Reception/Pasteurisation, Seperator, Homogeniser, Incubation Vessels, Render Machine, AutoPaker Machine, Tetra Pak, Skip Module, Tetra Pak Ice Cream Machine	Singh *et al.* (2014) alibaba.com (2016)	35.7+12.96+ 20.16+42.5+ 57.5+62.5+34+ 23.4+41.4= 330.12sqm	330.12sqm	50% =165
TY	None	None	Roto Mix machine, Compost Pakin	Wright-Pierce (2005) www.remooablefuel.com (2016)	8.64+15.12 =23.76sqm	23.76sqm	50% o =11
	None	None	Boiler, Chiller, Compreesor Clean-in-Place System	Singh *et al.* (2014) ckard (2002) alibaba.com (2016)	19.44+12+ 16.8+10.08 =101.88sqm	101.88sqm	50% =50.9
	None	None	None	Pickard (2002)	None	8.64sqm	8.6
	None	None	None	Pickard (2002)	None	40.5sqm	40.
	None	None	Chairs and Desk	Case Study (2015)	8sqm	8sqm	50% =
	None	None	Chairs, Desks, Shelves	Case Study (2015)	36sqm	36sqm	50% o =1

MACHINE SCHEDUL

YOGURT PRODUCTION



NAME:SENSORY YOGURT FILLING SOLUTION YAO-ME
SPACE REQUIRED: 15m x 6m
CAPACITY:30,000 cups/hour



NAME:NITZSCH Homogenizer Machine
SPACE REQUIREMENT: 4m x 4m

Cups



NAME:SUCCESS Automatic Rotary Piston Filling Cups Machine
SPACE REQUIRED: 10m x 3m
CAPACITY: 6000/hour

Tetra Pak



NAME:TetraPak Yoghurt Automatic Machine
SPACE REQUIREMENT: 10m x 4m (approx.)
CAPACITY: 6000 cups/hour

MILKING CENTER



NAME:ZEUS High efficiency herringbone milking parlour/counter milking technique equipment
PRODUCTIVITY: 82 cows per hour



NAME:Shanghai stainless steel tank
CAPACITY: 320_40320SL

6 Milk Center
1 : 100

MILK PREPARATION



NAME:Long life 6000L Hot water blow out Automatic control
SPACE REQUIREMENT: 600*300*600cm



NAME:SSA Dairy Separator
SPACE REQUIREMENT: 2m x 1.5m



NAME:FLUKE Automatic Liquid Storage Tank
CAPACITY: 100-10000L



NAME:FLUKE Homogenizing machine 300L-3000L
CAPACITY: 300-3000



NAME:Jacorg Complete fresh butter processing machine
SPACE REQUIREMENT: 1200*350*150cm
CAPACITY: 150 ton/day

CATTLE TREATMENT



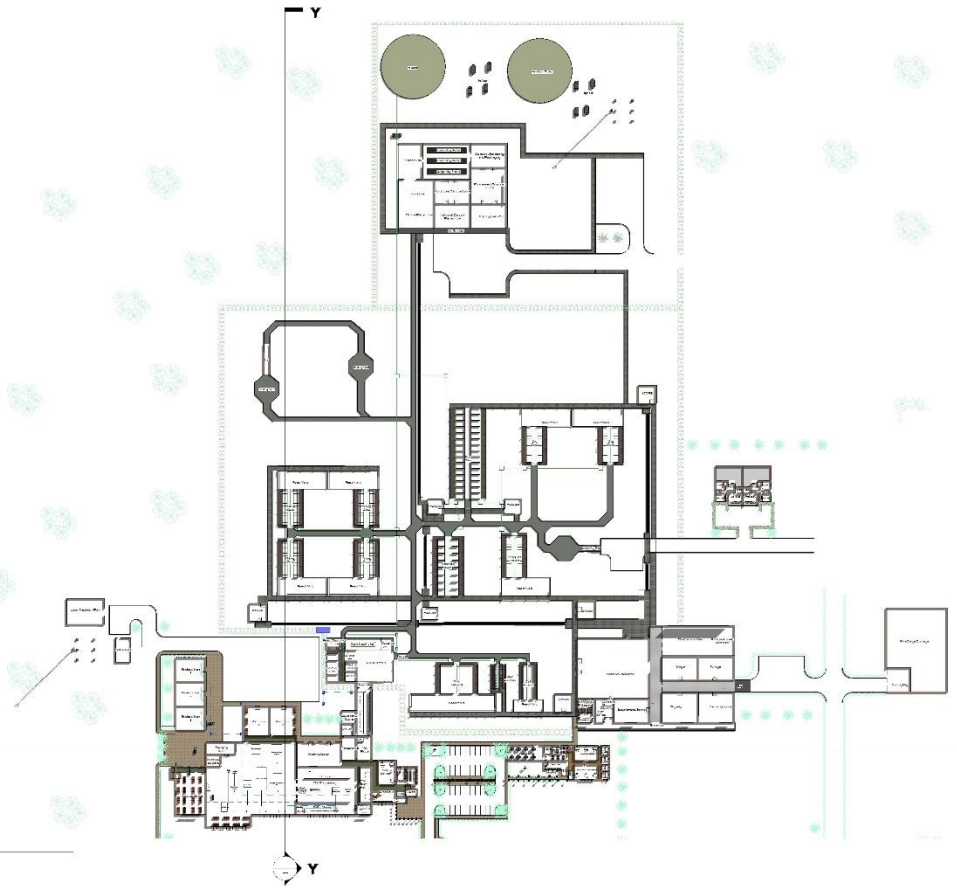
NAME:SP-9539 Solid Portable Alloy PVC Mouth
SPACE REQUIREMENT: 5m x 2m

1 Veterinary Unit
1 : 100

Appendix E: Proposed Model Dairy Farm, Kaduna

SITE PLAN
LEGEND
FARMSTE
FEED SER
FEED CON
CATTLE TR
MANURE C
PROPOSED MODEL DAIRY FARM, KADUNA
USING DESIGN STRATEGIES TO ACHIEVE SUSTAINABLE WASTE MANAGEMENT ON DAIRY FARM DESIGNS
REG NO: MS
MAJOR SUPE
MINOR SUPE
12/2

FLOOR PLAN



REG NO: MS
MAJOR SUPE

SOUTH VIEWS



PROCESSING PLANT



LIVESTOCK/ADMIN/FEED MILL

NORTH VIEWS



LIVESTOCK/PROCESSING PLANT



FEED MILL/PROCESSING PLANT