BIOCLIMATIC RESPONSE IN DESIGN OF FACULTY OF ENVIRONMENTAL SCIENCES IN THE HOT DRY CLIMATE OF YOBE STATE UNIVERSITY (YSU), DAMATURU

BY

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BY

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A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA

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DEPARTMENT OF ARCHITECTURE, FACULTY OF ENVIRONMENTAL DESIGN, AHMADU BELLO UNIVERSITY, ZARIA
NIGERIA

MARCH, 2015

DECLARATION

I declare that the work in this thesis entitled "Bioclimatic Response in Design of Faculty of Environmental Sciences in the Hot Dry Climate of Yobe State University (YSU), Damaturu" has been carried out by me in the department of Architecture. The information derived from the literature has been duly acknowledged in the text and a list of references is provided. And that no part of this thesis was previously presented for another degree or diploma at this or any other Institution around the world.

.....	.....	.....
IDRISS, Saidu	Signature	Date

CERTIFICATION

This thesis entitled "BIOCLIMATIC RESPONSE IN DESIGN OF FACULTY OF ENVIRONMENTAL SCIENCES IN THE HOT -DRY CLIMATE OF YOBE STATE UNIVERSITY (YSU), DAMATURU" by Saidu IDRISS meets the regulations governing the award of the degree of Master of Science of the Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

I dedicated this thesis research entitled “BIOCLIMATIC RESPONSE IN DESIGN OF FACULTY OF ENVIRONMENTAL SCIENCES IN THE HOT DRY CLIMATE OF YOBE STATE UNIVERSITY (YSU), DAMATURU” being a community service, to my late father (Malam Idrissa Garu) and mother Malama Hamsatu) who have all passed away during the period of this study. This work is part of the keen discipline given to me by my parents since childhood up to this level and therefore I pray for Allah to grant them an abode in Aljannatul-fir-dausi, amen summa amen.

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ABSTRACT

Thermal comfort in buildings located in hot dry weather conditions is improved architecturally with the use of appropriate and adequate bioclimatic design principles. Relationship between bioclimatic design principles and indoor thermal conditions are studied on three selected faculty buildings in north east Nigeria: School of Environmental Technology, Abubakar Tafawa Balewa University Bauchi; School of Environmental Sciences, Modibbo Adama University of Technology Yola and Faculty of Sciences, Yobe State University Damaturu. Firstly, visual survey checklist is used to assess the rates of bioclimatic response on each building. Then the indoor thermal conditions and indoor user perceptions about the buildings were synchronously assessed through physical and subjective measuring instruments. The thermal variables were measured according to morning and evening sessions for three days in this study covering: indoor air temperature, indoor air relative humidity and indoor air velocity. It is discovered that the percentage of adequately applied principles (AAP) on the buildings had direct (1:1) relationship to the indoor thermal comfort conditions. When AAP is at a high of 40%, comfort votes about the measured thermal parameters in these buildings revealed about 50% of indoor space users to be thermally uncomfortable within the indoor spaces: (47% of indoor users were uncomfortable with the 31ºC indoor air temperature; 43% of indoor users were uncomfortable with the 33RH% indoor air relative humidity but about 100% of the respondents were comfortable with the indoor air speed). The study concludes by proposing design concepts with integrated bioclimatic responses for the hot dry climate in designing buildings which is believed to upgrade the indoor thermal discomfort conditions for at least up to 80% of indoor space users in the study area.

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LIST OF ACRONYMS

YSU	Yobe State University, Damaturu
MAUT	Modibbo Adama University of Technology (MAUT), Yola
ATBU	Abubakar Tafawa Balewa University (ATBU) Bauchi
pMm	Physical Measurements taken in the Morning
pMa	Physical Measurements taken in the Afternoon
Pn	Coded Hot-Dry Bioclimatic Design Principles
AAPn%	Percentage of Adequately Applied Principles for the area
IAPn%	Percentage of Inadequately Applied Principles for the area
NAPn%	Percentage of None Applied Principles for the area
sMm	Subjective Measurements taken in the Morning
sMa	Subjective Measurements taken in the Afternoon
°C	Degree Celsius as a unit of Temperature
Arch	Architecture Department
Bldg	Building Technology Department
EMT	Environmental Management Technology Department
EM	Estate Management Department
ID	Industrial Design Department
QS	Quantity Survey Department
LVS	Survey and Geo-Informatics Department
URP	Urban and Regional Planning Department
Geo	Geography Department
GIS	Surveying and Geo-Informatics Department

DEFINITIONS OF TERMS AND CONCEPTS

In the course of this study, terms are used which specially require explanations as used by the researcher. These are as follows:

i. *Climate*: - is the state of atmosphere over long periods, usually tracked for more than 30 years of time, in a particular area.

ii. *Hot Dry Climate:* - is the climate of a particular region as characterised by very high solar radiation levels, high ambient temperature and relatively low air humidity.

iii. *Bioclimatic Building:* - is a building that responds to the climatic conditions of its environment, modifying them with appropriate design in order to create conditions that provide the lowest possible energy consumption, **thermal** and visual comforts to its user.

iv. *Thermal Comfort:* - is the state of mind about the conditions of a particular region expressed as the rates of ambient temperature, relative humidity and wind velocity.

v. *Anemometer:* - is the instrument used for the measurement of air velocity. Digital anemometers give approximate values automatically.

vi. *Hygrometer*: - is the instrument that measures relative humidity of air. Relative humidity is the ratio of the amount of water vapour in the air compared to the maximum amount of water vapour that the air could hold at that particular temperature.

vii. *Thermometer:* - is the instrument used for the measurement of temperature. Air temperature is a measure of the average speed at which air molecules are moving; high speeds correspond to higher temperatures.

viii. Thermal Comfort Questionnaires Survey: - is a form of questionnaires designed to enquire on thermal comfort perceptions about the building users in a particular site.

1.0 CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Buildings located in hot dry areas must adapt the extreme conditions of heat or cold to achieve a well-balanced indoor climates (Academia, 2014). Basic principles of bioclimatic design are the achievement of least possible energy consumption concurrently with the provision of thermal and visual comfort for the user of the building (Energy Design Partnership, 2013). Bioclimatic response addresses the problem of indoor thermal discomfort.

The climatic conditions of Yobe State (the site) is hot and dry for 6 -8 months of the year. And that the mean temperature for most meteorological stations in the state is about 37ºC. The maximum daytime temperature of about 45ºC is normally experienced in April, while minimum daytime temperatures of about 30ºC are usually recorded in December (Community Portal of Nigeria, 2012). In all the hot dry climates, relative humidity is low, as it drops to about 20RH% during the day time in this periods. And then there is a marked high wind velocity that drives the heated outdoor air into the indoor. And so remain the dry air moving rapidly enough to create drought conditions (Fislisbach and Zollikon, 1993).

Thermal comfort in school buildings is one of the problems necessarily of great interest when potential links between building performance, general sustainability, and the benefits of a healthy, productive and comfortable environment are considered. Schools are major energy consumers, due to significant demands for heating and cooling to provide acceptable thermal comfort conditions for inhabitants (Haddad, 2014). A comfortable classroom keeps students focused and alert (American Modular Systems, 2014). The relationship between indoor environmental conditions in general and student achievement is well established.

An Annual Reports (1982 – 1999) National Universities Commission, Abuja, Nigeria: bridging the gap between the north and the south; presented the analysis of jamb enrolments in Nigerian University new entrants. The six highest states in the south and six lowest states in the north. From the six northern states, the least enrolments was recorded in Yobe state as against the higher number of enrolments in the six southern states when quota is considered.

Recent studies show that education in Yobe is in sorry state due to population explosion into major towns, inadequate facilities, death of quality teachers and instructional materials (Press Interview, 2014). The illiteracy level and the need for education in the north is prevalent particularly in the north-east (study area). Coupled with the current insecurity, particularly in Yobe, the situation is critical that the need to undertake the project of school building designs cannot be over emphasised.

The study is imperative considering the place of indoor thermal comfort on learning input/output in school setup and the energy implications of maintaining a building by mechanical means. Building maintenance tends to make maintenance expenditure untenably high as the fuel prices rise coupled with the recent subsidy removal and the current instability of electricity in hot dry area.

1.2 Problem Statement

Poor vegetation cover and the Sahelian semi desert features of building sites within Yobe: coupled with the high solar radiation led to hot-dry cold weather conditions for the period of 6 - 8 months of dry seasons. In this weather condition, there is always a natural possibility that school buildings generate undue indoor thermal discomfort to the occupants leading to the following problems: students' performances and instructors' abilities to impact knowledge got decreased; the energy consumptions for buildings'

maintenance become unaffordable as the University community increases in population each day and also the health status of indoor users get critically threatened (Haddad, 2014); the type of dress indoor users wear is greatly changed (British Health and Safety Executive, 2012); etc.

1.3 Aim and Objectives of the Research

The research aim is to investigate bioclimatic design principles, their applications and relevance on achieving an indoor thermal conditions for buildings in hot-dry area. The result of this investigation leads to the design of the proposed Faculty of Environmental Science for Yobe State University.

The research will be led through the following objectives.

1. To identify the principles of bioclimatic design.
2. To determine the appropriate bioclimatic design principles for hot dry climate.
3. To establish a relationship between appropriate bioclimatic responses and the resultant indoor thermal conditions of buildings in the study area.
4. To propose design concept for a model building in the study area.

1.4 Research Questions

The research is guided by the following questions.

1. What is Bioclimatic Response?
2. What bioclimatic responses are appropriate in the Hot-Dry Climate?
3. What is the relationship between the bioclimatic responses and the resultant indoor thermal conditions of buildings in the study area?
4. What design concepts would be appropriate for a model building in the study area?

1.5 Scope and Delimitation of the Research

Bioclimatic design principles are not restricted on the issues of "thermal comfort studies" alone, it touches energy efficiency and visual comfort as well. That is to say, bioclimatic design principles could cover vast areas extending beyond the objectives of this research. The research is however limited to the stated aim and objectives due to the consideration of such factors as time, research laboratories plus the cost of financing a synoptic weather data for the highest accuracy. The case studies and field studies were conducted in the study area to obtain data about the relation of bioclimatic responses and corresponding indoor thermal conditions in the faculty buildings. Any other detail that goes further than the above statements is beyond the scope of the research.

1.6 Justifications of the Research

The proposed project hopes to provide one of the immediate needs of a University Faculty Building for the Yobe State University (YSU) Damaturu. Thermal discomfort was presented as the daunting phenomenon for building users in the area and therefore a sustainable design approach (Bioclimatic Response) to prevent the harsh weather features of the given site became imperative. Research findings as the end product of this study will be the design concepts for the proposed project but will also be recommended for use on any other upcoming developmental plans within the Climate.

The research hopes to contribute knowledge on the relationship between bioclimatic responsive buildings and their indoor thermal conditions in hot dry school environment.

1.7 Thesis Prospectus

Chapter 1: Presents background studies about the problem including unanswered questions that necessitated the aim and objectives in the research. Scope and Delimitation, Justifications and Thesis Prospectus were also indicated.

Chapter 2: Presents what the previous researchers were able to carry out on some similar thesis statements in their own ways. It also indicates how the following research was different from the previous works.

Chapter 3: Presents the methodology adopted for the research. Research assumptions about the respondents/thermal conditions and research reliability were also discussed.

Chapter 4: Presents case studies/field studies information that lead to research findings.

Chapter 5: Reports the design of conceptualised solutions to the findings of the research.

Chapter 6: Presents the recommendations/conclusions of the research including the contributions to knowledge that were finally drawn from the research.

2.0 CHAPTER TWO: LITERATURE REVIEW

2.1 The Concept of Bioclimatic Design

Edwards (2011) bioclimatic refers to the relationship between climate and architecture. It has a long pedigree going back to the work of Le Corbusier with his use in hot climates of ventilating atria, solar screening and thermal mass. Modernism drew inspiration from vernacular climatic practices whether in hot or cold regions. Climate is currently emerging as a new force in sustainable design- whether it be concern over mitigating the effects of climate change or by actively engaging in climate responsive design. Understanding climate within and around buildings offers the chance to remodel practice and save energy and water.

According to the Energy Design Partnership, energy solutions (2012) bioclimatic design is otherwise a form of sustainable design that is a complex process, which must consider issues of energy interaction between a building and its environment. Regardless of whether the attention focuses on passive or active systems, the energy performance of the building at all times and seasons determine the success of the design. That the objectives of bioclimatic design are:

1. To save and to replace some or all the fuel consumption for heating, cooling and other needs of habitable space
2. To ensure that the internal conditions are within the comfort zone and
3. To ensure a short-term depreciation of its additional initial costs compared to a conventional building, through the energy savings it leads to

For these purposes bioclimatic design combines the use of renewable energy (solar, wind, etc.) by regulating the heat flow (insulation, waterproofing, ventilation, and shading) based always on the climate data and building goals.

2.2 Principles of Bioclimatic Design

Energy Design Partnership, energy solutions (2012) identified the Principles of Bioclimatic Design accordingly as follows:-

1. Regulation of environmental conditions
2. Exploitation of solar energy
3. Thermal protection of buildings through shading
4. Systems and passive cooling techniques
5. Natural lighting
6. Acoustic control

Fislisbach and Zollikon (1993).postulated that the aim of design in hot-dry regions involves minimizing heat gain during the daytime and maximizing heat loss at night in and around the buildings to the occupant's comfort conditions according to the following design objectives:-

1. Resisting heat gain by:
    i. Decreasing the surface of the building exposed to the outside.
    ii. Using materials that take a longer time to heat up
    iii. Providing buffer spaces between the living areas and the outside
    iv. Decreasing ventilation during daytime in the summers.
    v. Providing adequate shading devices.
2. Promoting heat loss by:
    vi. Providing for ventilation of various appliances used.
    vii. Increasing ventilation during cooler parts of the day time.
    viii. Providing for evaporative cooling (e.g. roof surface, balcony, etc.).
    ix. Using earth coupling systems like earth-air pipes.

From section 2.2 above, the Principles of Bioclimatic Design that are relevant for adaption in building designs to be located in hot-dry areas are found to be PRINCIPLE 1 (Regulation of environmental conditions); PRINCIPLE 3 (Thermal protection of buildings through shading) and PRINCIPLE 4 (Systems and passive cooling techniques) accordingly. The principles provides detailed parameters on how to solve or dispel the indoor thermal discomfort architecturally in building designs.

2.2.1 Regulation of environmental conditions (microclimate improvement)

The improvement and adjustment of environmental conditions occurring on the construction of the building is succeeded with the overall strategic planning of the building in order to make the best use of the sun, the prevailing wind, the ambient temperature and humidity. See Fig. 2.1

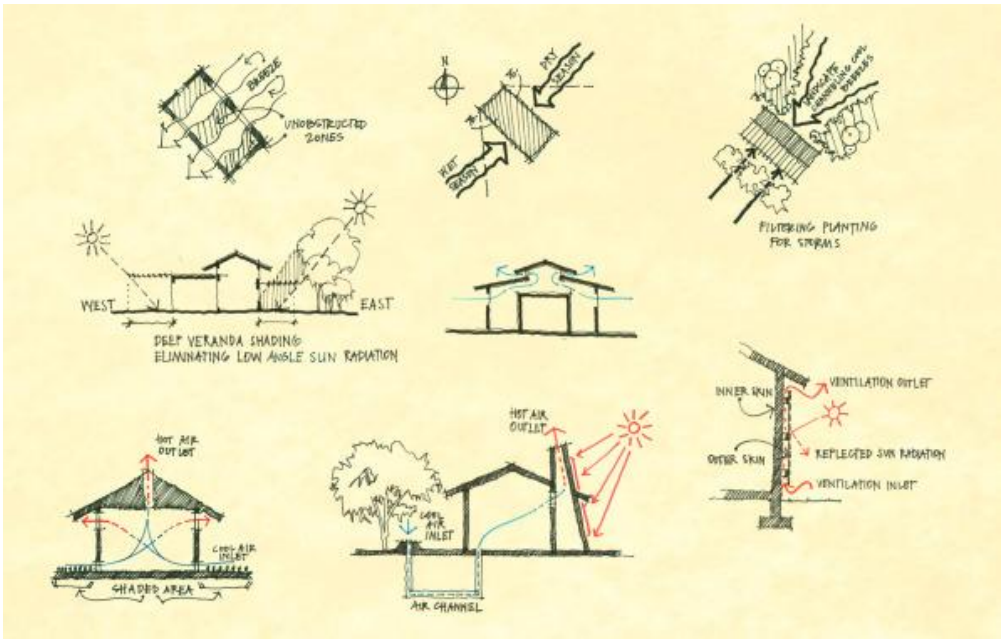


Figure 2.1: Regulation of environmental conditions
Source: Handbook on energy conscious buildings

2.2.2 Thermal protection of buildings through shading

The thermal protection of a building is mainly achieved by the appropriate design of the openings to prevent the escape of heat, the proper insulation of the building envelope and

the proper arrangement of the internal spaces (rooms used more frequently are placed in the south to avoid the ‘cold’ north).

With the protection of shading the major goal is to protect the building from overheating during summer with by strategically placing internal or external, vertical and horizontal blinds. See Fig. 2.2

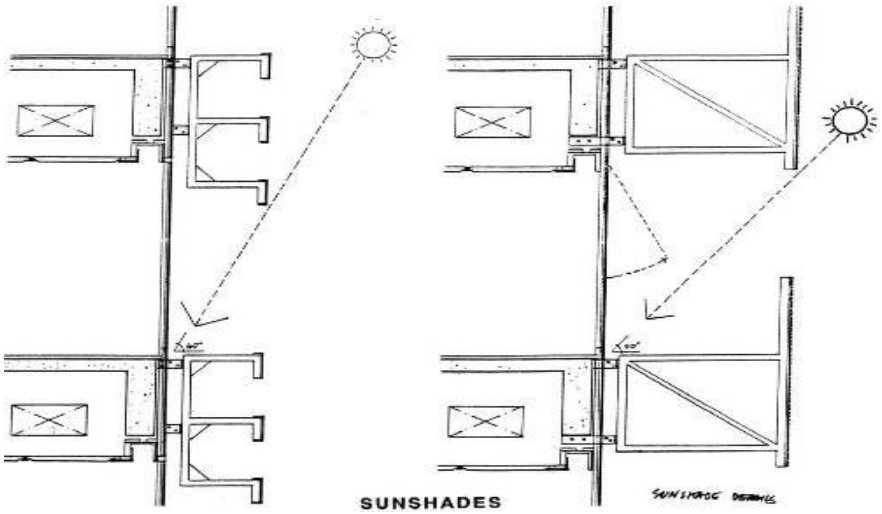


Figure 2.2: Thermal protections by shading devices.
Source: Handbook on energy conscious buildings

2.2.3 Systems and passive cooling techniques

It refers to the building’s microclimate control, its shading and to the minimization of thermal loads during the warm summer months through openings and the shading of the opaque envelope components. See Fig. 2.3

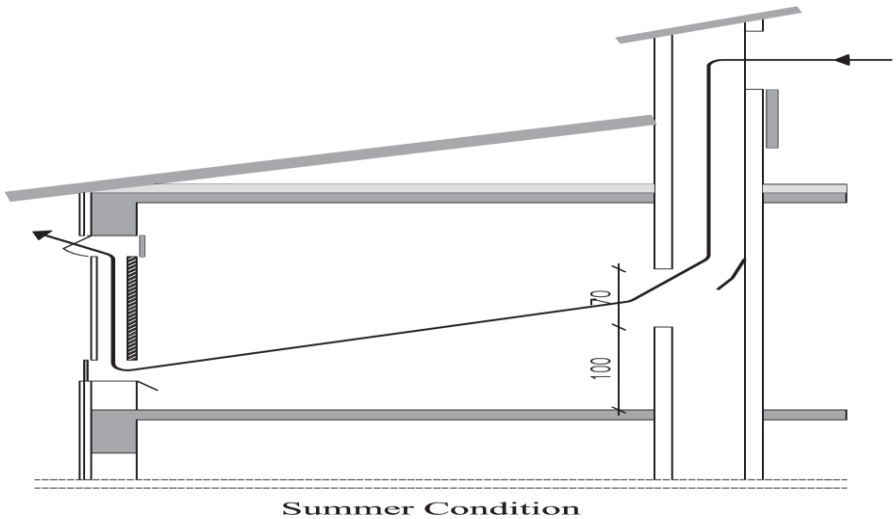


Figure 2.3: System and passive cooling
Source: Handbook on energy conscious buildings

2.3 Models of Bioclimatic Design in Hot Dry Climate

Models of bioclimatic design are provided in Handbook on energy conscious buildings by Kumar (2010). The practical applications of bioclimatic design for the hot dry climate are:

1. Site

    i. Landform

    ii. Water bodies

    iii. Street width and orientation

    iv. Open spaces and built form

2. Orientation and plan form

3. Building envelope

    v. Roof

    vi. Walls

    vii. Fenestration

    viii. Colour and textures

    ix. Special Considerations

2.3.1 Site

2.3.1.1 Landform:

Regions in this zone are generally flat and heat up uniformly.

In case of an undulating site, constructing on the leeward side of the slope is preferred. This protects the building from direct impact of hot winds which can be quite uncomfortable. See Fig. 2.4

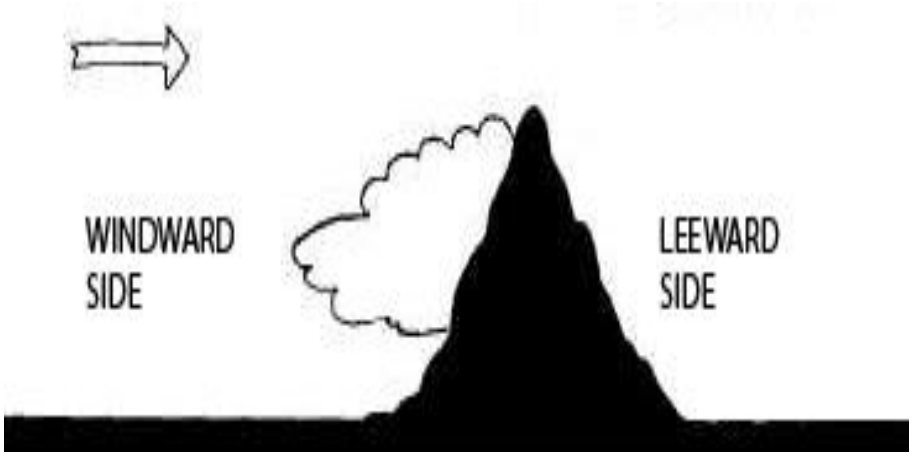


Figure 2.4: Undulating site
Source: Handbook on energy conscious buildings

Building in a depression is preferable in cases where ventilation is assured. See Fig. 2.5

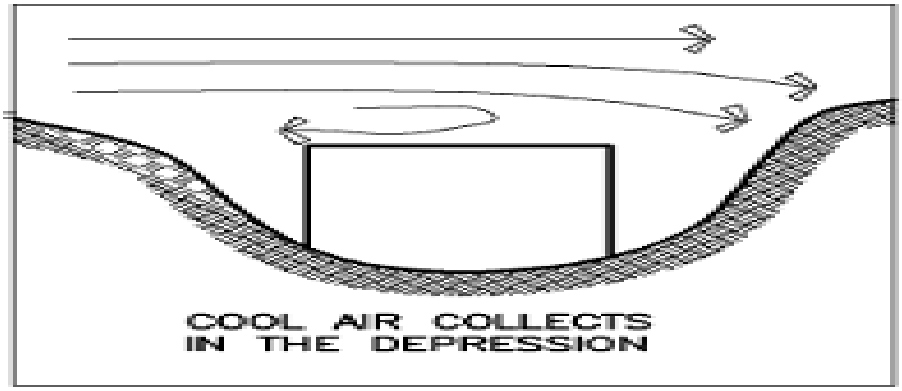


Figure 2.5: Building site at depression
Source**:** Handbook on energy conscious buildings

2.3.1.2 Water bodies:

Water bodies like ponds and lakes act as heat sinks and can also be used for evaporative cooling. They humidify the air and make it comfortable inside. See Fig. 2.6

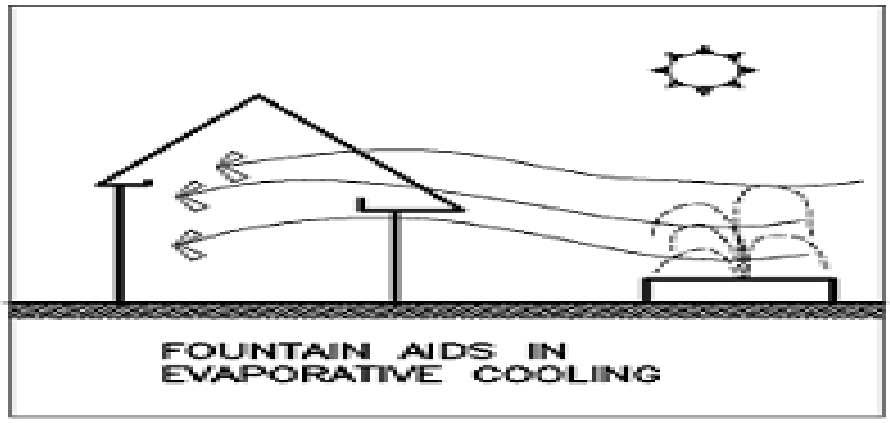


Figure 2.6: Evaporative cooling of fountains
Source: Handbook on energy conscious buildings

Fountains and water cascades in the vicinity of a building also aid in cooling. Fig. 2.7

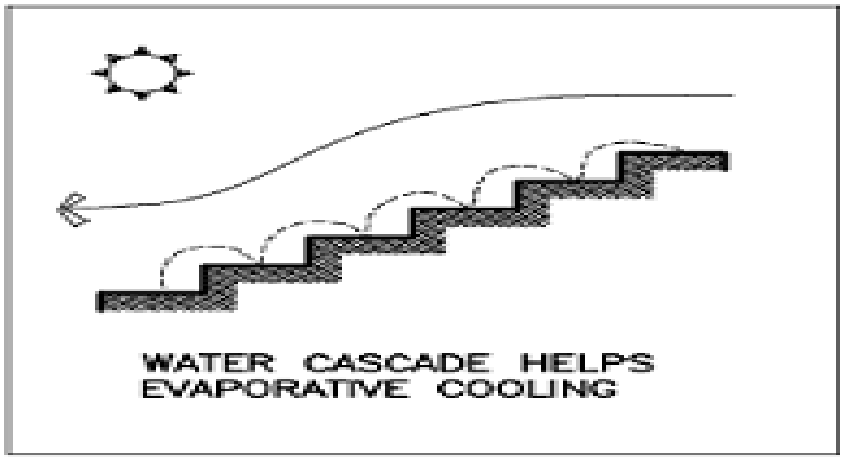


Figure 2.7: Evaporative cooling of water cascade
Source: Handbook on energy conscious buildings

2.3.1.3 Street width and orientation:

Streets must be narrow so that they cause mutually shade the buildings. Streets need to be oriented in the north-south direction to block solar radiation. See Fig. 2.8

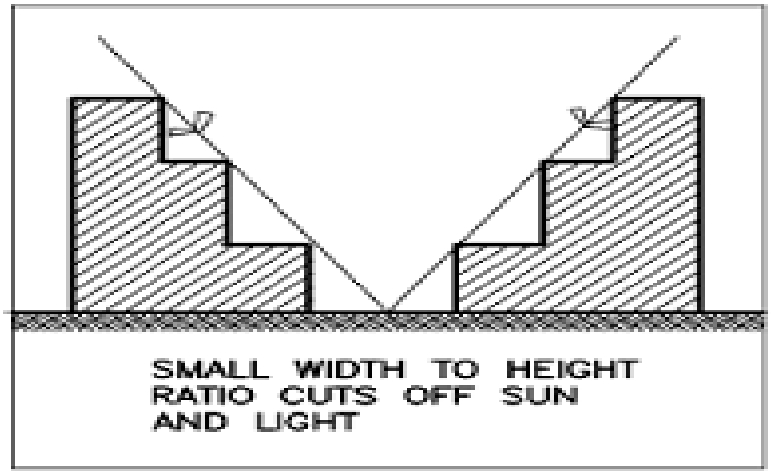


Figure 2.8: Narrow width to height ratio shades buildings on site
Source**:** Handbook on energy conscious buildings

*2.3.1.4 Open spaces and built form***:**

Open spaces such as courtyards and atria promote ventilation. They can be provided with ponds and fountains for evaporative cooling. Courtyards act as heat sinks during the day and radiate the heat back at night. Grass can be used as ground cover to absorb solar

radiation and aid evaporative cooling. Earth beaming can help lower the temperature and also deflect hot summer winds. See Fig. 2.9

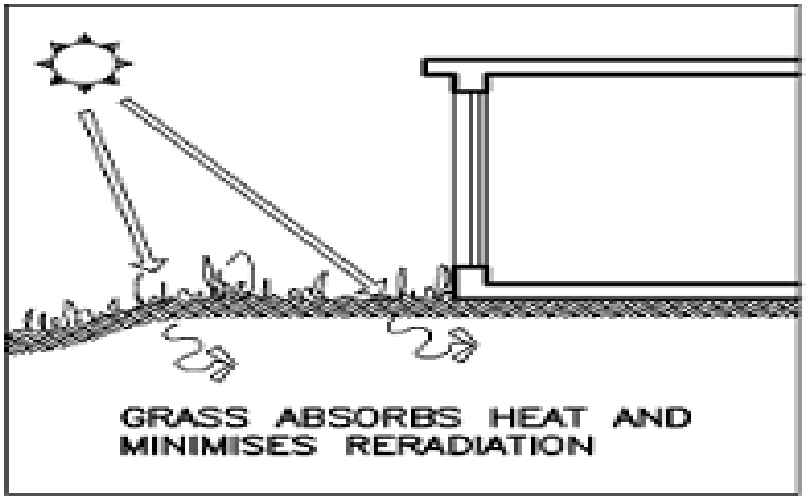


Figure 2.9: Absorption of heat by ground cover grasses
Source**:** Handbook on energy conscious buildings

2.3.2 Orientation and plan form

An east-west orientation is preferred in hot and dry climatic regions. See Fig. 2.10

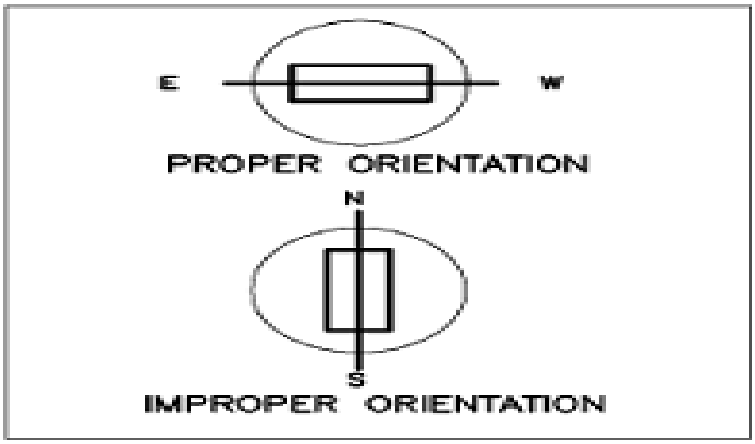


Figure 2.10: Correct Orientations
Source**:** Handbook on Energy Conscious Buildings

South and north facing walls are easier to shade than east and west walls. During summer, the south wall with significant exposure to solar radiation in most parts of India, leads to very high temperatures in south-west rooms. Hence, shading of the south wall is imperative. The surface to volume (S/V) ratio should be kept as minimum as possible to reduce heat gains. See Fig. 2.11

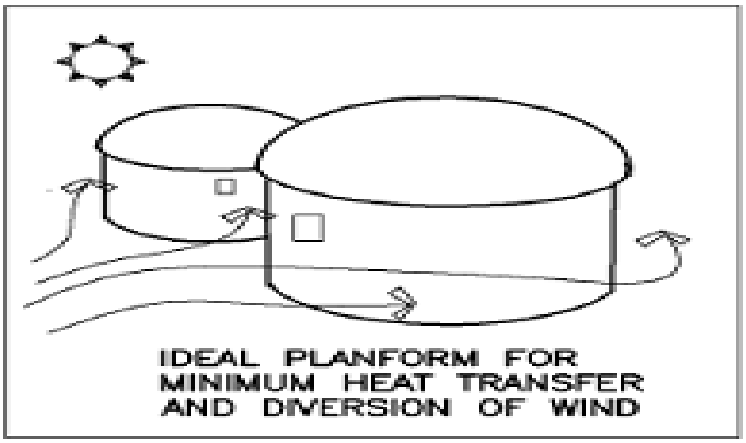


Figure 2.11: Ideal plan forms for diversion of wind
Source: Handbook on energy conscious buildings

Cross-ventilation must be ensured at night as ambient temperatures during this period are low.

2.3.3 Building envelope

2.3.3.1 Roof:

Flat roofs or vaulted roofs are ideal in this climate. Nonetheless, a vaulted roof provides a larger surface area for heat loss compared to a flat roof. See Fig. 2.12

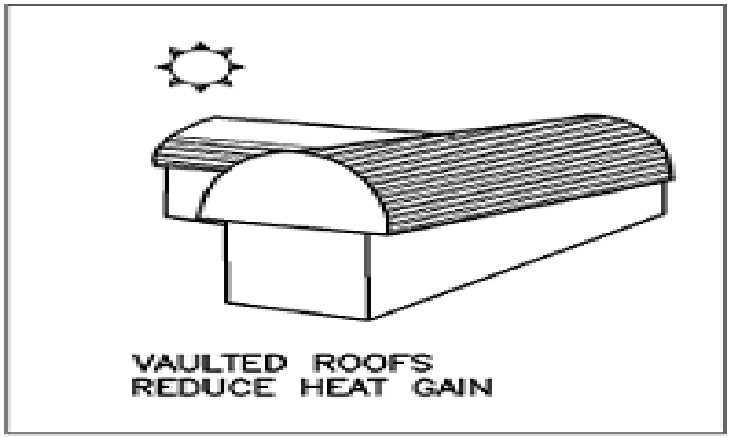


Figure 2.12: Vaulted roof reduce heat gain
Source**:** Handbook on energy conscious buildings

The material of the roof should be massive; a reinforced cement concrete (RCC) slab is preferred to asbestos cement (AC) sheet roof.

External insulation in the form of mud phuska with inverted earthen pots is also suitable.

A false ceiling in rooms having exposed roofs is favourable as the space between the two acts as a heat buffer. Thermal insulation over false ceiling further increases the buffer action.

Insulation of roofs makes the buildings more energy efficient than insulating the walls.

Evaporative cooling of the roof surface and night time radiant cooling can also be employed.

In case of evaporative cooling, it is better to use a roof having high thermal transmittance.

2.3.3.2 Walls:

In multi-storied buildings, walls and glazing account for most of the heat gain. The control of heat gain through the walls by shading, thus, becomes an important design consideration. A wall that transmits less heat is feasible here.

2.3.3.3 Fenestration:

In hot and dry climates, reducing the window area leads to lower indoor temperatures.

More windows should be provided in the north facade of the building as compared to the east, west and south as it receives lesser radiation throughout the year

All openings should be protected from the sun by using external shading devices such as chajjas and fins. See Fig. 2.13

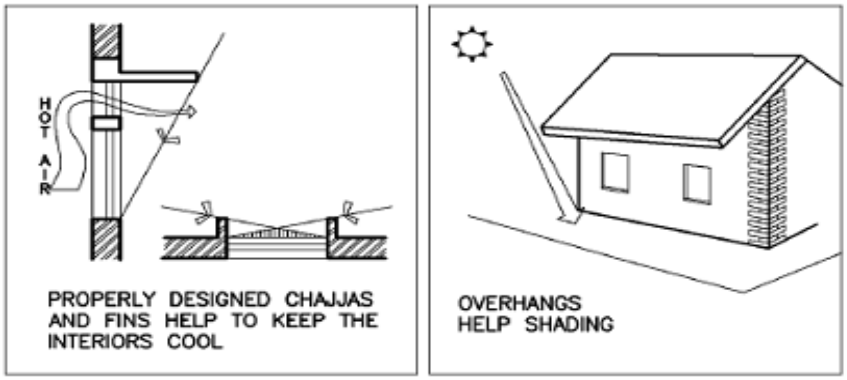


Figure 2.13: Shading devices and overhangs give heat protection
Source: Handbook on energy conscious buildings

Moveable shading devices such as curtains and venetian blinds can also be used.

Ventilators are preferred at higher levels as they help in throwing out the hot air.

Since daytime temperatures are high during summer, the windows should be kept closed to keep the hot air out and opened during night-time to admit cooler air.

The use of 'jaalis'(lattice work) made of wood, stone or RCC may be considered as it they allow ventilation while blocking solar radiation. Scheduling air changes (i.e. high ventilation rate at night and during cooler periods of the day, and lower ones during daytime) can significantly help in reducing the discomfort.

The heat gain through windows can be reduced by using glass with low transmissiveness.

2.3.3.4 Colour and textures:

Change of colour is a cheap and effective technique for lowering indoor temperatures.

Colours that absorb less heat should be used to paint the external surface.

Darker shades should be avoided for surfaces exposed to direct solar radiation.

The surface of the roof can be of white broken glazed tiles.

The surface of the wall should preferably be textured to facilitate self-shading.

2.3.3.5 Special Considerations:

As the winters in this region are uncomfortably cold, windows should be designed such that they encourage direct gain during this period.

Deciduous trees can be used to shade the building during summer and admit sunlight during winter.

Well-insulated and very thick walls give a good thermal performance if the glazing is kept to a minimum and windows are well-shaded.

In case of non-conditioned buildings, a combination of insulated walls and high percentage of glazing will lead to very uncomfortable indoor conditions as the building will tend to act like a greenhouse with the insulated walls preventing the radiation from the windows from escaping into the environment.

Indoor plants can be provided near the window, as they help in evaporative cooling and in absorbing solar radiation.

Evaporative cooling and earth air pipe systems can be used effectively in this climate.

Desert coolers are extensively used in this climate, and if properly sized, they can help in achieving comfort levels

2.4 Climate

The National Geographic Education Society (2012) defined climate as the long-term pattern of weather in a particular area. Weather is the state of the atmosphere over short periods of time. Weather can change from hour to hour, day to day, month to month or even year to year. A region's weather patterns, tracked for more than 30 years, are considered its climate. World climates, as studied by meteorologists, display a wide range of complex characteristics and variations. For building design purpose it is important to make use of a standardized version of the climate classification system around the world.

Energy Design Partnership, energy solutions (2012) stated in accordance to the definitions above that the basis of bioclimatic building and bioclimatic design is climate. And that the factors and mechanisms that affect are:

1. The sun, with parameters of solar geometry and sunshine
2. The air temperature,
3. The wind with parameters the direction and intensity and
4. Moisture with parameters the humidity of air and the environment

The proper observation of these elements and a building design based on their "exploitation" and integration to the lead to the so-called energy design which can drastically reduce the energy consumption of a building and its negative environmental impact.

2.4.1 Climate classifications

The National Geographic Education Society (2012) gave the twelve (12) different types of climate found on Earth:

1. Tropical Climate
    i. Tropical Wet Climate
    ii. Tropical Wet and Dry Climate
2. Moderate Climate
    i. Humid Subtropical Climate
    ii. Mediterranean Climate
    iii. Marine West Coast Climate
3. Continental Climate
    i. Humid Continental Climate
    ii. Subarctic Climate
4. Polar Climate
    i. Tundra Climate
    ii. Ice Cap Climate
5. Dry Climate
    i. Arid Climate
    ii. Semiarid Climate
6. Highland Climate

All the twelve (12) climate types are grouped into 5 categories, except 1 (Highland). Climates in the same category share characteristics and are usually found in the same area. Climates change over time which is usually very slow. The Earth has experienced many different climates over its 4.54 billion years. There are many different factors that cause climates to shift and change. (See Fig. 2.14)

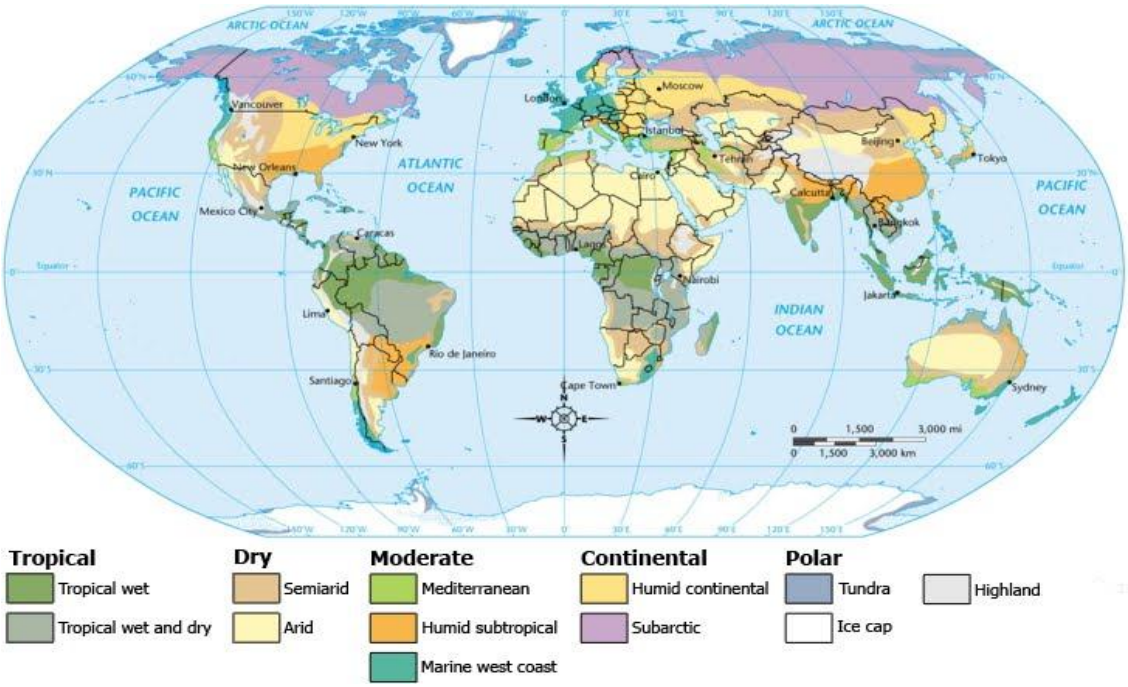


Figure 2.14: Climatic zones in the world
Source: National Geographic Education Society, 2012)

2.4.2 Semiarid (hot dry) climatic zone in yobe state

National Geographic Education Society (2012) defined the hot dry climate to be in the arid zone as above which is in either of the two zones of latitude that are between 15° and 30° north and south of the equator, consisting mostly of desert or semi desert. In this type of climate, the mean summer temperatures are around 30°C but can reach a maximum of 45°C. Clear nocturnal skies can cool temperatures down as low as -10°C. Relative humidity is low and precipitation is very low. This lack of moisture, together with strong seasonal winds, can make wind-borne sand storms a major problem.

According to Community Portal of Nigeria (2012) the climate of Yobe State is hot and dry for most periods, of the year. The mean daytime temperature for most stations in the state is about 37°C. In summer, the highest temperature (about 45°C) is normally experienced in April, while minimum temperatures (about 30°C) are usually recorded in December (Lloeje, 1977). The State exhibits a remarkably high annual range of mean monthly temperatures.

The Ministry of New and Renewable Energy, MNRE, (2010) stated that a hot-dry climatic region is characterised by very high radiation levels, high ambient temperature and relatively low humidity. It is also characterised by a mean monthly maximum temperature above 30°C. The region in this climate is usually flat with sandy or rocky ground conditions. Other countries that are found in hot-dry climate include Saudi Arabia, Oman, United Arab Emirates, Egypt, Syria, Chad, Sudan, and Niger.

The characteristics of aridity according to Soomro, (2012) are:-

1. High summer day time temperatures (32-36°C)
2. In hotter regions above 40 and up to 50°C
3. Large diurnal temperature range (15-20°C
4. High solar radiations (800-900 w/m²)
5. Frequent dust storms,
6. Little or no rain
7. Clear sky most of the year, promoting solar heating during the days and
8. Long wave radiant loss during the nights.

2.4.3 Comfort zone in yobe state

Thermal comfort is that condition of mind which expresses satisfaction with the thermal environment, that is, when someone confirmed as not feeling either too hot or too cold. (British Standard, EN ISO 7730). An environment can be judged a reasonable comfort when at least 80% of its occupants are surveyed and found out that they were satisfied with their conditions (British Health and Safety Executive, 2012)

The American Society of Heating, Refrigeration and Air-conditioning Engineers (55 – 2010) conducted research over many years on large numbers of people concluded that there is a range of combined temperatures and humidity that provides comfort to most

people (80%) in any climate. The *Comfort Zone Chart*, shows “Indoor Air Temperature" on the vertical axis, "Relative Humidity" on the horizontal axis, and a shaded area known as the "*Comfort Zone*." It is also provided that an Ideal condition of temperatures range is between (36°C - 46°C) and 45% RH year round. For Air speed, there is a relationship between temperature, humidity and comfort: People will be comfortable with higher temperatures in the hot condition, if the air is moving and/or the relative humidity is low (near 30%). On the other hand, people will be comfortable with lower temperatures in the cold condition, if the air is still and/or the relative humidity is high as 60%. (See Fig. 2.15)

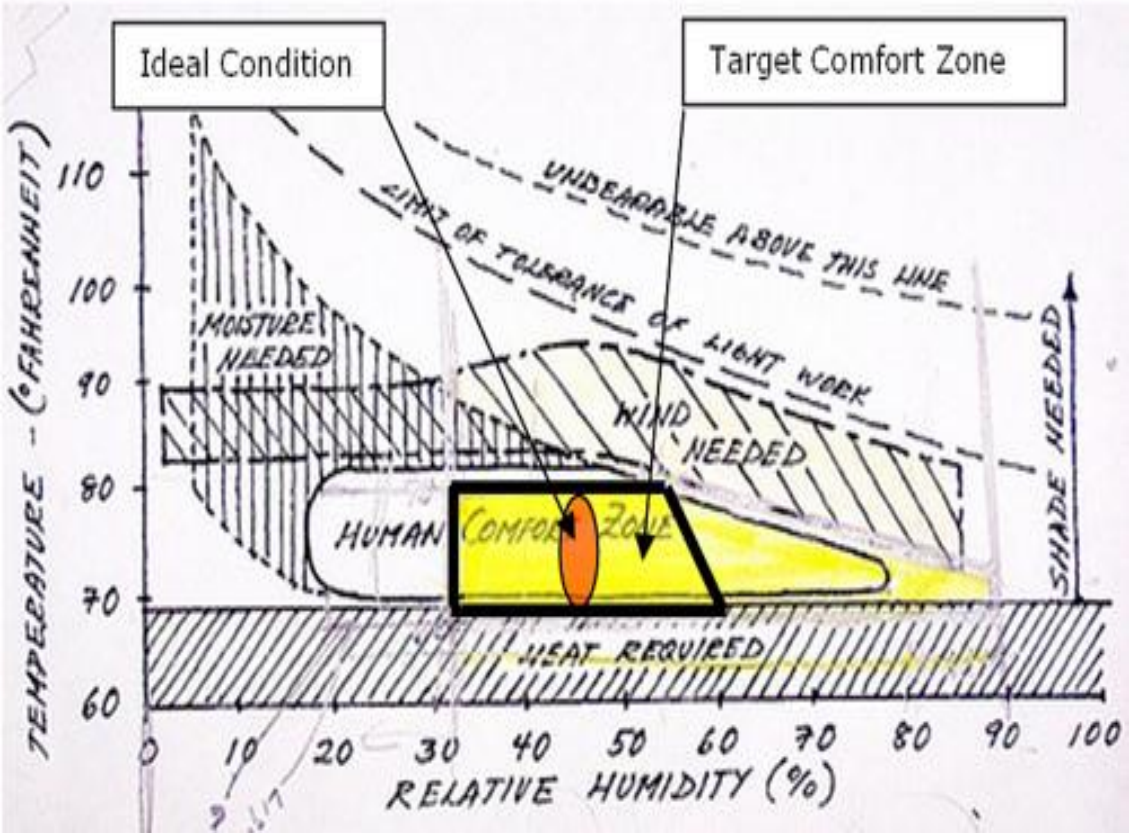


Figure 2.15: An ideal human comfort zone in any climate
Source: ANSI/ASHRAE Standard 55, 2010

From the Figure 2.15 above, there is no one temperature and humidity condition at which everyone is comfortable. People are comfortable at a range of temperatures and humidity. Notice that most people are comfortable at higher temperatures if there is a lower humidity. As the temperature drops, higher humidity levels are still within the comfort

zone. This makes sense if you think about your own experience. Remember being in a hot, dry, desert-like environment and being surprised at how you didn't feel hot. That's the effect of humidity and temperature on human comfort.

Occupational Safety and Health Service (1997) provided a thermal comfort standard for sedentary occupations applicable in any climatic zone. According to the standard, most people will be thermally comfortable for the following conditions as shown Table 2.1

Table 2.1 Standard Conditions for Sedentary Occupations by OSHS - New Zealand, 1997

Conditions	Values	
	Summer/ Rainy Season	Winter/ Dry Cold Season
Air temperature	19-24°C	18-22°C
Relative humidity	(0.12) 40-70%	
Air speed	0.1-0.2 m/s, without creating a draught	
Radiant heat	No direct exposure to a radiant heat source	
Clothing	Light clothing (0.5clo)	Winter clothing (1.0clo)

2.5 Challenges of Locating a Building in Hot Dry Conditions

The success or failure of any bio-climatically designed building could be judged not only on how it is designed but also maintained in the region. In this way, the greatest barriers to achieving thermal comfort are the following challenges (Concept Bio, 2008).

1. Designing According to Individual Taste/style In line with the Bioclimatic Guidelines. Bioclimatic design imposes a set of guidelines, but there still remains a lot of freedom to design according to individual taste. Sitting of the building, consideration of solar access, collection of rainwater, using thermal mass to your advantage, correct fenestration and solar shading are all good examples of techniques

that can be taken into account when designing. The end product is much more energy efficient and in tune with its surroundings and Nature.

2. Selection of Landscaping Plants to be used in the Climate. Plants in hot and dry climates must be selected based on their resistant to draught conditions and height limit for this design since shade is needed for almost year round. Since hot dry climates tend to have weather conditions that are hot to very hot, low precipitation, and dry air. Plants that are naturally grown in these climates must already become adaptive to the conditions overtime. Even though there are often long periods without any rainfall and the sunshine became very intense yet some plants such as wildflowers, cactus, Succulents, drought grasses and Shrubs survived. In this design, Table 2.2 gave some of the plants out of which are purposely selected.

Table 2.2 Some Plants/Trees Adaptable to Drought Conditions (Turfgrass Producers International TPI, 2014)

Plants/Trees	Common Name	Botanical Name	Mature Height
1.	Mango Tree	*Mangifera indica*	15m
2.	Cashew Tree	*Anacardium occidentale*	12m
3.	Mahogany	Meliaceae	23m
4.	Umbrella Tree	Taxodiaceae	20m
5.	Neem Tree	Azadirachta Indica	15m
6.	Cactus	Cactaceae	Short
7.	Wildflowers	-	Dwarf
8.	petunia		Dwarf
9.	Drought grasses		Ground cover
10.	Daisy		Low

3. Permanent Source of Water Supply to humidify air and irrigate plants. Boreholes are drilled at relevant positions on site while overhead tank is raised to generate potential difference of driving/powering the water down the channels.

2.6 Summary of Previous Researches

Previous works have been summarised as follows:

1. The principles of bioclimatic design is aimed at achieving the least possible energy consumption concurrently with the provision of thermal and visual comfort for the user of the building (Energy Design Partnership, E.D.P. energy solutions, 2013).
2. In hot-dry region, the objectives of bioclimatic design are the lowering of both daytime and night-time temperatures in and around the buildings as much as possible to the comfort conditions (The Ministry of New and Renewable Energy, MNRE, 2010).
3. Studies were made on the use of six primary factors affecting thermal sensation as either environmental or personal parameters on thermal comfort. These factors are air temperature, mean radiant temperature, air velocity, humidity, metabolic rate and clothing (American Society of Heating Refrigerating and Air Conditioning Engineers, ASHRAE 2007). Research has also shown that other contributing parameters affect thermal comfort; these include climate change with time, building and its services, and occupants' perception (Nicol and Humphreys 2002, Evans 2003 and Hellwig*et al.* 2006).
4. Thermal comfort in buildings is defined as the state of mind for the building occupants to be satisfied with their indoor thermal environment having desire for neither a warmer nor a cooler condition (Fanger 1970).

5. Studies have also shown that the occupants in the tropic environment have a higher heat tolerance and can adapt to the environment that they are used to (Hussein I., and Rahman M. H. A., 2009).

2.7 Research Gaps

1. Bioclimatic design assessments were aimed at low energy design, thermal and visual comfort through the use of visual survey and photographing techniques alone without the use of measuring instruments.
2. Thermal comfort assessments previously conducted were not related to bioclimatic designing: Nicol, 1995 in Hussein, 2009 postulated that the best representation of how thermally comfortable a building is depend on the occupant' predictions derived from field studies with questionnaires.
2. Building design was not cognizance of user tolerance to the hot dry weather conditions.
3. The following instruments (visual survey checklist on bioclimatic principles, photographs, measuring instruments and questionnaires) generate bioclimatic response – thermal comfort relationship.
4. The technique of using multiple instruments generate additional data which was not previously presented in the reviews.

2.8 Architectural Design Considerations for Faculty Buildings

Design considerations are formulated to bring to the attention of building designers in applying the universal design principles and requirements to the type of buildings and facilities. It is therefore recommended that the content of building projects and community facilities, especially those intended for general use, should be taken into account by designers from the inception stage of the design (Architectural Services Department – United States, 2011).

2.8.1 Faculty of environmental sciences

Faculty of Environmental Sciences is a multi-programme unit of a University Education providing training in a number of disciplines relating to the environmental studies. Another important feature of a Faculty of Environmental Sciences is the introduction of six-year continuous professional degree programmes. The six-year programme consist of four years pre-professional education followed by two years of specialized professional training terminating in the award of graduate and post-graduate degrees respectively. Faculty of Environmental Sciences is designed with at least more than two of the following academic departments: Architecture department, Building department, Estate management department, Urban and Regional Planning department, among others (Mooreadvice, 2012). For technical/artistic subjects, like architecture, art, music, etc., there must be spaces of Workshops, Administrative, Design studios, Teaching, Circulations, Offices, Postgraduate Units, etc. Faculty buildings are designed, as a rule, within 2-3 storeys heights. Higher only in exceptional cases. Workshop buildings with heavy machines or frequent deliveries are single storey only. (Architect's Data, third edition)

2.8.2 Space allocation

Time saver standards, Neufert and Architect's handbook provided the scope and limitation of the faculty building complex as determined by the following space needs: Research/Workshop spaces, Administrative space, Practical/Design studio spaces, Teaching spaces, Circulation spaces, Offices, for both Graduate and Postgraduate Units, etc.

1. Research/Workshop spaces: - University libraries are organised in either one or two layers. The one layer system is administered centrally (book processing and services) and normally has very few separate branch or subjects libraries. The two-

layer system includes a central library and usually large number of faculty, subject and institute libraries. Workshops should have enough space for sufficient work area just as workstation in office design. Firstly, temporary stores for partially finished stocks and general stores must be designed. Secondly, administration and management need work office, technical offices, management secretarial offices, meeting room, etc.

2. Administrative space: - the space provided for the management staff whose task is to manage the affairs of the faculty is another form of office space. At faculty and departmental levels, staff are accommodated in their respective offices within the administrative block. Office areas will have separate offices for one to three people with workstations for trainees, group offices for up to 20 people.

3. Practical/Design studio spaces: - each drawing studios requires (3.5 – 4.5) m^2, depending on size of drawing table (1.9 – 2.3) m^2. Drawing table of dimension for Ao size (920 x 1270) mm as fixed or adjustable board. Drawings cabinet for storing drawings flat, of same height as drawing table, surface can also be used to put things on. There must be table tops for putting things on, drawing cabinets for hanging drawings or storing flat, suitable for Ao at least. Each workplace should have a locker.

4. Teaching spaces: - this include standard classrooms, supplementary classrooms, extra-large classroom, or special courses, also rooms for teaching materials and other ancillary rooms. Space requirements: classroom for traditional teaching 2.00m^2/pupil; for teaching in sets 3.00m^2/pupil, for open plan teaching 4.50m^2/place including ancillary areas needed for each subject. The standard room shape: rectangular or square (12 x 20, 12 x 16, 12 x 12, 12 x 10) m with a

maximum room depth of 7.20m. It is possible to have windows on one side only. Floor areas are: traditional classroom, 1.80 – 2.00m²/pupil; open plan 3.00 – 5.00m²/pupil. The clear height should be 2.70 – 3.40m.

5. Circulation spaces: - horizontal and vertical circulation usually double as an emergency escape route. Escape route must be 1.25m, other escape routes 1.00m Maximum length of escape routes: 25m measured in a straight line from the stairwell door to the furthest workplace, or 30m in an indirect line to the centre of the room. Circulation are the spaces provided within the designed spaces to accommodate traffic activities which are necessary for either management and/or other functions. Like the walkways, the galleries, the verandas, etc.

6. Offices, the way in which office work is organised and roles are defined (office structure, students/visitors management, office technology) affects the requirements for office space. The space allocated to a person to execute a task is referred to as a workstation. Office area requirements are calculated in two parts. Firstly, people space is calculated as (standard individual space x number of people) + allowance for immediate ancillary needs + a factor (usually 15%) for primary circulation. Secondly, non-people space (e.g. machine rooms, libraries and the like for which fittings and equipment sizes are more important than staff numbers in setting the area requirements) should be calculated by informed estimates based on existing good practice or comparable examples + an additional factor for primary circulation.

2.8.3 Planning data

Design handbooks (Time saver standards, Neufert and Architect's handbook) provides bench mark for the planning of spaces for both the staff and students according to the above requirements. Table 2.3 presents the planning data to be considered.

Table 2.3 Planning data for floor area of various space allocations.

Space name	Minimun	Maximum	Heights	Remarks
Classrooms	120m²	240m²	3.2m - 3.8m	
Offices	80m²	85m²	As above	
Corridors/gallery and walkways	2.4m	4.0m	flexible	
Lecture hall/Conference hall	12m	20m	4.5m – 6.0m	
Studios/senior staff offices	76m²	138m²	3.2m - 3.8m	40 – 60 drawing boards are refered
Parking space	11.5m²	16.5²	Open space	
Workshops	400m²	1400m²	4.5m – 6.0m	
Library	100m²	120m²	3.2m - 3.8m	

Source: Researcher's Preliminary Studies, 2014

Table 2.3 presents planning data for different floor area to be used in relation to the type, shape and sizes of spaces in question.

Table 2.4 Planning data for studio/office/workshop furniture arrangements

Dimensions	Length/Width	Depth	Hieght	Remarks
Desk	1.3m	0.5m – 0.6m	0.8m – 1.0m	
Cupboards		0.8m – 1.2m	1.2m – 2.0m	
Stool	0.3m - 0.4m		0.6m – 0.7m	
Between desk to desk	0.65m	-		
Front desk to black board	2.0m	-		
Between two desks	0.6m	-		
Desk to window	0.6m	-		
Desk to cupboards	0.95m	-		

Source: Researcher's Preliminary Studies, 2014

Table 2.4 presents planning data for the arrangements of fittings to be used in relation to the type, shape and sizes of furniture selected.

2.8.2 Services requirements

There is constant pressure to improve environmental standards within designed spaces to improve the health of indoor users (American Modular Systems, 2014). Some of the aspects of the building services which will be treated in this section are lighting, ventilation, fire safety, power supply, clean and storm water supply:

1. Lighting: - Daylight is now a requirement for all schools but direct sunlight must be controlled and health risks avoided. Supplementary artificial lighting in form of up lighters and down lighters reduces glare and contrast, and enhances the character of the classroom at night times. Lighting levels and colour should ensure correct colour rendering and that all indoor users, instructional materials and written notes on the board can be clearly seen without strain or dazzle.

2. Ventilation: - well-balanced and easily managed environmental conditions within the faculty complex is essential to the smooth running of the school. The current trend, supported by most users, is to move away from full air-conditioning and provide natural ventilation with open able windows. This will subject the indoor spaces to wider temperature fluctuations but this can be minimized by operable or manual operations to control the conditions.

3. Fire Safety: - as fire protection, a wider staircases of width of 2.4 - 4.0m is recommended to allow the high number of people in the storeys under the state of emergency of fire outbreak to escape the building safely. The staircases must be linked up from the lower level and then bifurcated at each floor along the middle

leading to the wings of the building.. The use of void at the stair wells from ground to the upper floors allow for alert and control of fire at administration block within the gallery.

4. Power Supply: - as a means of alternative energy source, solar panels and a standby generator, of 250KVA, was recommended for the building as an alternative to the NEPA supply which is unreliable. The solar power and the generator would take care of the sudden or eventual power failures.

5. Clean Water supply: - bored hole must be drilled on site to water the fountains, landscape trees, and building water needs. Sustainable storage facilities must be provided to reserve large volume of water for eventual usage. In this way, overhead tank should be positioned at upper floor for greater potentials.

6. Storm Water Drainage: - storm water drainage as either collected down the roof gutters, site surfaces and used off in conveniences should be taken care of through the use of various drainage basins in the form of surface and underground gutters.

2.9 Bioclimatic Design Considerations

In order to respond adequately and effectively to the problem of thermal discomfort using bioclimatic design principles, the following concepts were developed and presented for building designers' usage in the study area in (Fislisbach and Zollikon, 1993):

1. The design forms
2. The site
3. The building on the site
4. The building envelope

1. The design forms: - The forms must be chosen and designed based on the principles of bioclimatic responses.

2. The site: - The site surface must be landscaped with grasses as ground cover against the site surface heating. This must cover an area of up to 40% of total site size so that at least the ratio of green area to built-up becomes 1:3. To cater for maintenance difficulty, drought resistant grasses were given as solution.

3. The building on the site: - Fountains must be designed within and outside courtyards on the site to help humidify the air and make it thermally comfortable inside. Plant evaporative cooling like roof garden and balcony garden must be designed from ground up to higher level to filtrate as well as cool the incoming air to the indoor spaces. Drought resistant plants must also be selected to help sustain the maintenance expenditure.

4. The building envelope: - massive construction of external/enveloping walls may provide the full solution in regulating indoor conditions to the comfort of indoor users.

3.0 CHAPTER THREE: METHODOLOGY

The methodology that best suits the research is the case study: Case study method is widely applied in practice oriented fields such as environmental studies, social work, education, and management sciences, Johansson (2010). Accordingly, the intended methods and approaches followed are discussed below.

3.1 Research Design

The case study of three institutional/faculty buildings located in three different States in North-east Nigeria (School of Environmental Technology, Abubakar Tafawa Balewa University Bauchi; School of Environmental Sciences, Modibbo Adama University of Technology Yola and Faculty of Sciences, Yobe State University Damaturu) is conducted in this research.

The first two faculty buildings are assessed more of their bioclimatic responses alone like orientations, shading devices, thermal massing, correct number and sizes of openings etc. The third case studies three field studies buildings within the faculty complex (Lecture Hall building, Classroom building and Laboratory building) are assessed for the relationship between the bioclimatic responsiveness of buildings and the indoor thermal conditions in the area.

The field studies were carried out on Thursday, 30th Jan. 2014 – (Day 1), Friday, 31st Jan. 2014 – (Day 2) and Monday, 3rd Feb. 2014 – (Day 3) this time is considered the driest period in the state (Desert Research Center – Damaturu, 2014). As the research focuses on establishing a relationship between the Indoor thermal comfort conditions and the applied Bioclimatic Responses on buildings in the study area, it is then important to conduct the study on buildings considered bioclimatic responsive during the driest period where the users find the weather condition to be thermally most uncomfortable.

3.2 Sampling Techniques

For the purpose of Architectural Design studies within the hot dry climate of north-eastern states of Nigeria, an architectural design considerations were studied from the sampled case studies in the area. Samples are manageable units drawn from the wider population of the study. The following criteria presented the reason for their selection:

1. The case study building must be located within the study area,
2. The case study building must a University Faculty of Environment,
3. The case study building must give detail information on Faculty Design.

Case study 1- In Bauchi State, School of Environmental Technology, Abubakar Tafawa Balewa University Bauchi was studied.

Case study 2- In Adamawa State, School of Environmental Sciences, Modibbo Adama University of Technology Yola was studied.

For the purpose of establishing a relationship between the Indoor thermal conditions and the adequacy of Bioclimatic Responses on buildings located in the study area, three other case study buildings all within the third case study were selected:

Case study 3- In Yobe State, Faculty of Sciences, Yobe State University Damaturu the tree buildings' selection was based on the following Sampling Criteria:

1. The buildings occupants must be science oriented for easy responses to the thermal comfort questionnaire survey;
2. The buildings must be at and/or proximate to the proposed project site;
3. The buildings must be of the highest occupancy rates within the campus.

Hence, the following buildings were selected according to the above criteria:-

i. Lecture Hall building (100 seats)
ii. Classroom building (50 seats)
iii. Laboratory building (50 seats)

3.3 Data Sources

The primary sources of data are the information from case studies/field studies. While the secondary sources of data are the information from books, journals, articles, etc. All the relevant data used in this research are sourced from either of the following: these are visual surveys photographs and subjective user thermal states through the questionnaires in the case studies; and then books, sketches, articles, journals, etcetera from the literature review.

3.4 Data Collection Techniques

In the collection of data for this study, bioclimatic design data in form of checklist is first conducted on each of the three buildings on Day 1. This data is then compared to the synchronized field measurements (with measuring instruments as well as with questionnaires) conducted simultaneously for up to 3 working days on the same three buildings.

3.4.1 Bioclimatic design studies

Appropriate bioclimatic responses for hot-dry climate are coded (Pn) and tabulated from (P_1) up to (P_{22}) numbers. The listing of these principles from 1 - 22 is known as the checklist. There were three assessing scales on each row as were: *Adequately Applied Principles, Inadequately Applied Principles and Not Applied Principles and abbreviated* cumulatively as (AAPn), (IAPn) and (NAPn). The codes are then interpreted and formed into percentages on a pie chart according to applications. *Photographs* were graphically an additional data here. (See appendix I for sampled checklist).

3.4.2 Thermal comfort studies

3.4.2.1 Field measurement

This is termed as the *Physical measurements* (pM) in the study; morning session is coded (pMm) and afternoon session as (pMa). The field measurement focuses on measuring the

three thermal comfort parameters. The equipment used are ANEMOMETER (Model AM-4812) with accuracy of ± (2%+1d), 0.1 resolution as well as range of 0.4-30m/s for measuring wind velocity, HYGROMETER (wet and dry bulb) for measuring air relative humidity and THERMOMETER for measuring air temperature respectively. Indoor space was measured each case after calibrating the instruments to the referenced units for the purpose of reliability and accuracy of read-off values. The average values of the total points of measurements were recorded in the morning and afternoon sessions according to (pMm and pMa) respectively.

Due to the distribution of the effects of thermal variables in the indoor space, six numbers of points were marked within comfort zone for measurement taking at the Chemistry Lab. and Classroom buildings. While eight numbers of points were marked within the occupied zone for measurement taking at the Lecture Hall building. (Plate II). All the readings were taken at a height of 1.0 m above floor level, which represents the height of an occupant at seated level. The maintenance section of the faculty of science building operates between 9am until 5pm. It takes about (30 to 40 minutes) to trek between the three measuring points. And therefore readings were taken from 10 am to 5pm daily. The samples were recorded at every 1 hour interval, alternately repeated for all three locations for a total period of 3 days.



Plate I: Measuring instruments (Hygrometer, Anemometer and Thermometer)
Source: Researcher's field studies, 2014

3.4.2.2 Questionnaire Survey

This is termed as *Subjective Assessments* (sM) in the study; morning data are coded sMm and afternoon (sMa). In this, the Faculty Building is occupied by a total of 582 occupants (539 students and 43 staff). The faculty management granted permit for the researcher to conduct the study two weeks in advance of the study and consent was obtained for their staff to be approached and participate in the survey. Staff participation was encouraging in the study because the needed number took part in the study.

All students who were present on the research days took part. The list of staff and students in the faculty building made up the sampling frame. In light of the time and financial constraints, a 17.2% sample size (n=100) out of the population size (N=582) was used. However, taking into consideration the possibility of non-response, the study increased the sample size to 117 (20%). All participants' respondents answered the questionnaires within each building at the time of measurements. The survey was conducted at the respective occupied spaces of the respondents as follows (Lecture hall, Laboratory and Classroom). Although the respondents were free to decide if they wanted to participate in

the study or not. A total of 100 successful questionnaire surveys were completed yielding a response rate of 100%.

The thermal comfort questionnaire survey was adapted and edited by the researcher for the purpose of this study from: http://surveymonkey.com/s/VZWR6TM. It covered 4 sections. Its first section focuses on user's demographic information such as age, gender, background and designation. The second section deals with users' perceptions about the thermal environment in terms of the three thermal comfort parameters. The measures include air temperature (ranging from very warm to very cold), wind velocity (ranging from very windy to no wind), and humidity (ranging from very damp to very dry). The third and final section covers preferences to the bioclimatic design features (such as use of shading device, changing sizes of windows, repositioning of windows, etc. as well as opinions on the provision of comfort within buildings.

The subjective assessments basically treated for the research were respondents' vote (thermal comfort votes) in the occupied zone on the following: -

i.) *Thermal Preference Scale* was designed to assess how the perceived indoor thermal condition was preferred to change: 1(warmer), 0(no change), -1(cooler)

ii.) *Assessment of relative humidity Scale* assessed responses on how dry or wet the indoor condition was perceived: 1(air is wet), 0(air is just right), -1(air is dry)

iii.) *Assessment of air movement Scale:* 3 (much too still), -2 (too still), -1 (slightly still), 0(just right), 1 (slightly breezy), 2 (too breezy) and 3 (much too breezy).

The data collection followed the Morning (9-10am) and Afternoon (12-1pm) sessions. The plan for two-sessions and three-day activities were necessary to capture the different conditions and environmental changes at different hours of the day. Respondents' votes was based on the ASHRAE Standard (ANSI/ASHRAE) 55 – 2010

which specified an acceptable thermal environment to record 80% of occupants' vote as the *central three categories* (-1, 0, 1) of any subjective measurement.

3.5 Data Analysis and Interpretation

3.5.1 Bioclimatic design studies (BDS)

The relevant bioclimatic responses for hot-dry climate are coded (Pn) and tabulated from (P_1) up to (P_{22}) numbers. There were three assessment scales on each row as the: *Adequately Applied Principles (AAP), Inadequately Applied Principles (IAP) and Not Applied Principles (NAP)* are provided as options on the checklist.

The listing of these principles from 1 - 22 (appendix I) known as the checklist. The number of times an option is applied marked by ticking (×) cumulatively against the relevant principle as (AAPn), (IAPn) and (NAPn). It is used in the survey to determine the ratio of how the principles were variously applied on each building. The codes are then interpreted and formed into percentages on a pie chart according to applications. The survey data is illustrated in the following figures (1, 2 and 3) about each building showing the percentages of (AAPn%), (IAPn%) and (NAPn%) respectively. The *photographs* were graphically an additional data here.

3.5.2 Thermal comfort studies (TCS)

Physical measurements: The physical measurements (pM) were numerical values directly recorded as the readings on the instruments; {temperature (°C), relative humidity (Constant) and wind speed (m/s) respectively}. It is recorded as the indoor conditions when the thermal comfort questionnaire survey is administered to the indoor users. The morning session is coded (pMm) and afternoon session as (pMa) respectively.

Subjective Parameter Assessments: The subjective measurements (sM) are finally recorded and converted into percentages (%) of different levels of user comfort votes

about the perceived indoor thermal variables as indicated on relevant question. The morning data are coded sMm while sMa referred to the data collected in the afternoon. Analysis was finally made, in form of summary by the subjective measurements (sM) and physical measurements (pM) and then relating it to checklist data and hence bioclimatic design in a hot dry climate is assessed according to thermal comfort. Additional data was in form of tables, charts, figures/plates, description, explanations and etcetera. Refer to Chapter Four.

3.6 Research Assumption

All respondents were assumed to attain their comfort within the following conditions at the time of survey:-

- (27 – 34) °C Indoor Air Temperature
- (25 - 40) % Indoor Air Relative Humidity
- (0.4 – 0.7) m/s Indoor Air Velocity
- Cloth Constant (all wear universal type and culture guided type)
- Metabolic rate (Sedentary Activity)
- Age (18 – 40) years
- Gender (majority are male respondents)
- State of Health (all of them are Normal)
- Cultural expectation to clothing (is generally uniform among respondents)

3.7 Reliability and Validity of Research

The instruments were fully tested on previous researches. Prior to the actual survey, a pilot study was conducted at the Architecture department, ABU Zaria to examine the respondents' understanding to gauge thermal comfort questionnaires. Research assumptions were tested by pilot studies at the Classrooms of Yobe State University where the respondents comprised of science students. The final research respondents were

ensured science oriented students already at 400 level who are believed to be exposed to general environmental studies and at least spent like three (3) years staying in the faculty building ever ready to provide relevant information in the thermal comfort questionnaire surveys.

4.0 CHAPTER FOUR: CASE STUDIES/FIELD STUDIES

4.1 Architectural Design Case Studies

Two faculty buildings selected within the hot dry climate of north-eastern states of Nigeria as case study 1 and case study 2 are: the first case study was in Bauchi State, School of Environmental Technology, Abubakar Tafawa Balewa University Bauchi and the second case study in Adamawa State, School of Environmental Sciences, Modibbo Adama University of Technology Yola.

4.1.1 Case Study 1: - school of environmental technology, abubakar tafawa balewa university (ATBU) bauchi

4.1.1.1 Background information

The School was established in the year 1988 and presently has eight (8) number of academic departments. The academic staff and their office space needs are given as follows: Architecture Department (Arch) has twenty-four (24) staff, Building Technology Department (Bldg) has fourteen (14) staff, Environmental Management Technology Department (EMT) has twelve (12) staff, Estate Management Department (EM) has nineteen (19) staff, Industrial Design Department (ID) has twelve (12) staff, Quantity Survey Department (QS) has fifteen (15) staff, Survey and Geo-Informatics Department (LSV) has ten (10) staff, Urban and Regional Planning Department (URP) has fifteen (15) staff respectively.

4.1.1.2 Site Size/Layout

There are undergraduate programmes (5 years) as well as Postgraduate programmes (2 years) are currently run by the school; bachelors of Technology as well as Master of Technology are awarded.

The school is made up of three dispersed blocks of buildings (phase I, phase II and theatre) as shown on (Figure 4.1 and Plate III). It is housed under the three blocks of buildings all located in the University main campus as indicated: Phase I contain ground and first floor plans accommodating facilities of Industrial Design, Estate Management, Building and Urban and Regional Planning Departments), Phase II contains ground, first and second floor plans accommodating facilities of Architecture, Urban and Regional Planning, Estate Management Technology, Quantity Survey, and Land Survey Departments) while the theatre block accommodates level 2 – 5 students offering general courses and level 1 science students of the school. See Fig. 4.1

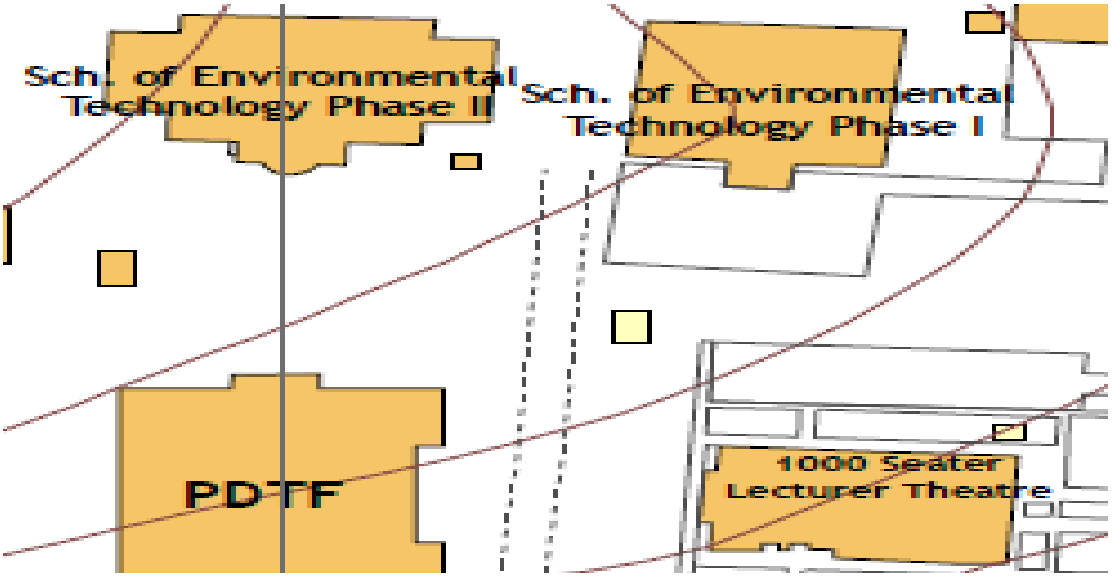


Figure 4.1: Base map of environmental school ATBU, Bauchi.
Source: ATBU Works Dept., 2014


Plate II: Left to right- Phase I, Phase II and Theatre Buildings Facades respectively.
Source: Researcher's Field Studies, 2014

4.1.1.3 Bioclimatic Response in design of case study 1

Square forms were design on site and the highest number of openings are orientated in the north-south directions. The enveloping or insulation of wall is made from hollow blocks 230mm thick. And so the wall thermal mass is fair. The vegetation cover is poor: the site landscape trees/plants are inadequate while there was no green roof and other roofing techniques to cool indoors. Water bodies was absent within the relatively flat site surface while the courtyards are adequate but the maintenance is poor. Mutual shading of interior/courtyard spaces is adequate. Openings on walls were too large and easy to introduce dust. Parapet was designed around the flat roofs against the high wind storm. Light colours were used as paints on site forms. Indoor plants are fairly used. The summary of bioclimatic response is provided graphically on Fig. 4.2

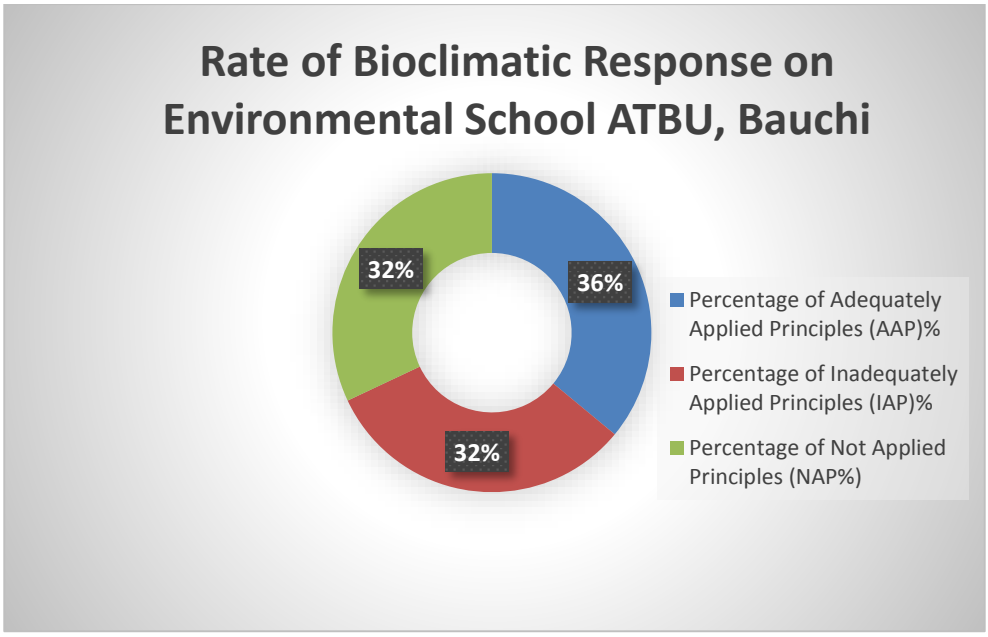


Figure 4.2: Rates of Bioclimatic Responses on Case Study 1.
Source: Researcher's Field Studies, 2014

Figure 4.2 above presents the rates of bioclimatic responses with respect to the case study 1: The percentage of adequately applied principles (AAP%) was 36%; the percentage of inadequately applied principles (IAP%) was 32% and the percentage of none applied principles (NAP%) was 32% respectively. This explains how only seven (7) of the

twenty-two (22) principles are adequately applied (mutual shades, open space as heat sink, minimised surface volume, flat/vaulted roofing, insulative ceilings, white/light colours, reflective surfaces and indoor plants) were used in the design of case study 1. Plates IV, V and VI is the photographs recorded during the survey.



Plate III: Vertical shading devices on Phase I and Phase II Elevations, at Environmental School, ATBU, Bauchi
Source: Researcher's Field Studies, 2014



Plate IV: Aerial views Environmental School ATBU, Bauchi showing casted shadow, courtyard, tall plants within courtyard, flat roof form, Aluminium roofing sheet, parapets,
Source: Researcher's Field Studies, 2014



Plate V: Scanty landscape in the courtyard of Phase I and Phase II respectively.
Source: Researcher's Field Studies, 2014

4.1.2 Case Study 2: - school of environmental sciences, modibbo adama university of technology (MAUT), yola

4.1.2.1 Background information

The School was established also in the year 1988 and presently has eight (6) numbers of academic departments. The academic staff and their space needs are given as follows: Architecture Department (Arch) has sixteen (16) staff, Building Technology Department (Bldg) has eight (8) staff, Geography Department (Geo) has sixteen (16) staff, Industrial Design Department (ID) has fifteen (15) staff; Surveying and Geo-Informatics Department (GIS) has thirteen (13) staff, and Urban and Regional Planning Department (URP) has fourteen (14) staff respectively.

4.1.2.2 Site size/layout

There are undergraduate programmes (5 years) as well as Postgraduate programmes (2 years) are currently run by the school: bachelors of Technology as well as Master of Technology are awarded.

The school is made up of typical plans of a block of departments. The typical blocks are distributed on the site as shown on Fig 4.3. Courtyards are the central marks for all blocks. It is housed in these five blocks of buildings within the University campus: Block I accommodates the facilities of Geo-Informatics department alone, Block II accommodates the facilities of Industrial Design and Building departments, Block III accommodates the facilities of Urban and Regional Planning and Architecture departments, and Block IV accommodates the lecturer's offices for the departments of Geography and Geo-Informatics departments. General lectures are conducted in the Theatre buildings reserved at the faculty of sciences.



Figure 4.3: Site overview, environmental science faculty MAUT, Yola
Source: Researcher's fieldwork, 2014

4.1.2.3 Bioclimatic response in design of case study 2

Rectangular forms were design on site and the highest number of openings are orientated in the north-south directions. The enveloping wall is made from hollow blocks 230mm thick and so the wall thermal mass is fair. Although the vegetation cover is good but maintenance was poor: the site landscape trees/plants are adequate with space that could nurture green roof techniques but the maintenance of such landscape was not made. Water bodies was absent within the relatively flat site surface. This endangered the indoor conditions of heating although courtyards are adequate but the absence of water render it inadequate. Mutual shading of interior/courtyard spaces is adequate. Openings on walls were also too large and easy to introduce dust. Parapet was designed around the flat roofs against the high wind storm. Light colours were used as paints on site forms. Indoor plants are fairly used. The summary of bioclimatic response is provided graphically on Fig. 4.4

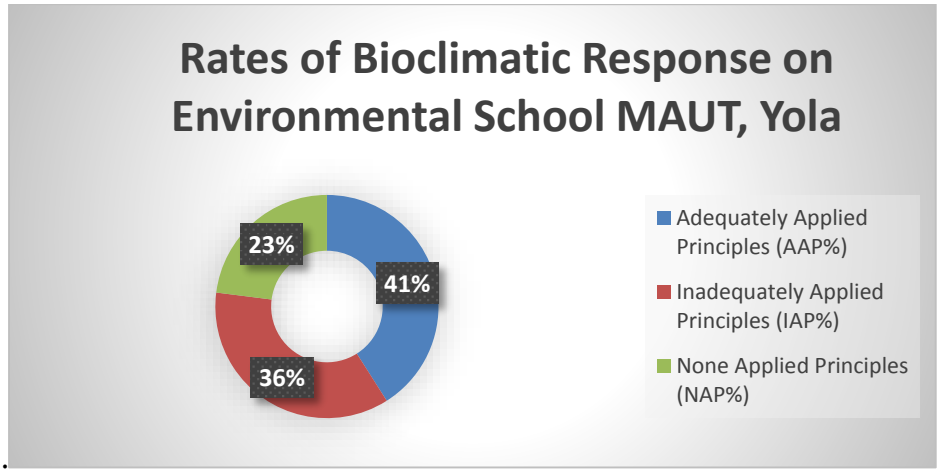


Figure 4.4: Rates of Bioclimatic Responses on Case Study 2.
Source: Researcher's Field Studies, 2014

Figure 4.4 above presents the rates of bioclimatic responses with respect to the case study 2 is such that: The percentage of adequately applied principles (AAP%) was 41%; the percentage of inadequately applied principles (IAP%) was 36% and the percentage of none applied principles (NAP%) was 23% respectively. This explains how only nine (9) of the twenty-two (22) principles are adequately applied (mutual shades, facades protections, open space as heat sink, correct orientations, flat/vaulted roofing, more openings on NS directions, use of white/light colours, reflective surfaces and landscape plants) were used in the design of case study 2. Plates VII, VIII and IX have shown some of the photographs recorded during the survey.



Plate VI: High level openings and low level openings facing courtyards
Source: Researcher's Field Studies, 2014



Plate VII: Scanty landscape within the courtyards due to poor maintenance culture.
Source: Researcher's Field Studies, 2014



Plate VIIJ: Facades with: high level openings, vertical shading devices, flat roofs, and parapets
Source: Researcher's Field Studies, 2014



Plate IX: Projected verandas, proper orientation, shady trees, hedges within the external building
Source: Researcher's Field Studies, 2014

4.1.3 Summary of case studies

Table 4.1 Summary of Bioclimatic Responses Assessed on the two Case Studies.

Architectural Design Elements	*Design Principles or Bioclimatic Responses*		*Rates of Bioclimatic Responses: - (Adequately Applied (AAP),Inadequately Applied (IAP) and Not Applied (NAP)*						*Coded Principles*
			CASE STUDY 1			*CASE STUDY 2*			
			AAP	**IAP**	**NAP**	**AAP**	IAP	NAP	
Site Landform	*Grasses as ground cover against windstorm.*				×		·	×	P1
Water bodies	*Water bodies in the vicinity of building*				×			×	P2
Street width and Orientation	*Narrow Distances between buildings*		×			×			P3
	Facades oriented or protected by landscapes				×	×			P4
Open Spaces and Built form	*Open spaces as heat sinks and heat radiator*		×			×			P5
	Evaporative cooling from grasses			×			×		P6
Orientation and Plan form	*Longest sides preferred facing N-S directions.*			×		×			P7
	Minimised surface to volume (S/V) ratio		×				×		P8
Building Envelope	*Roof*	*Flat or vaulted roofs are ideal in this climate.*	×			×			P9
		Use of Massive roofing sheets/materials		×			×		P10
		The use of indoor ceilings having good insulation value	×				×		P11

		Plant evaporative cooling on roof surface at night times			×		×		P12
	Wall	*Well-insulated or very thick walls for good thermal value*			×			×	P13
	Fene strat ion	*Reducing number and the window area*		×			×		P14
		More openings at north and south facades than east west		×		×			P15
		Use of external and internal shading devices		×			×		P16
		Desert coolers and/or ventilators at higher levels or Earth air pipe systems			×			×	P17
		-The use of materials made of wood, stone or RCC materials in great proportion			×		×		P18
Colour and Texture	*-Use of colours that absorb less heat such as white or textured surfaces*		×			×			P19
	Reflective surfaces		×			×			P20
Special Considerations	*Deciduous trees are used to shade the building during hot weather and then admit sunlight in the dry harmattan.*				×	×			P21
	Indoor plants can be provided near the window,		×					×	P22
Summary			**8**	**7**	**7**	**9**	**8**	**5**	**22**

Source: Researcher's Analysis, 2014

With reference to Table 4.1, the adequately applied principles (AAP) of BDS conducted on case study 1 and 2 were both not implemented in the design for as high as 50%.

4.1.4 Case studies results

The study show that four (4) out of the twenty-two (22) principles of bioclimatic design were found **not applied** (NAP) completely by designers in the design OF case study buildings. The principles are as follows:-

1. Design for ground cover grasses on site surfaces
2. Design for water bodies and courtyard
3. Design for controlling the heat transfer into the building
4. Design for evaporative cooling at low/high levels

4.1.5 Test of case study results

4.1.2.1 Research statement

S_1 = there is a significant percentage of none applied principles of bioclimatic design on buildings in the area.

S_o = there is no significant percentage of none applied principles of bioclimatic design on buildings in the area.

Decision rule

Accept S_1: {if a given P (n) = (NAP)n repeatedly observed on all case studies.

Reject S_o {if no P (n) = (NAP)n repeatedly observed on all case studies.

Case study results:

P1 (Ground cover grasses on site surfaces) = NAP repeatedly on all case studies

P2 (Water bodies and courtyard design) = NAP repeatedly on all case studies

P12 (Control of heat transfer into building) = NAP repeatedly on all case studies

P13 (Evaporative cooling at low/high levels) = NAP repeatedly on all case studies

The analysis of bioclimatic responses studied on the two case study buildings (school of Environmental Technology, Abubakar Tafawa Balewa University, Bauchi and School of Environmental Sciences, Modibbo Adama University of Technology (MAUT), Yola) showed that some of the principles (P)n of bioclimatic design were repeatedly recorded as NAP on all the cases. The place of these none applied principles of bioclimatic design must therefore be overemphasised for designer in the area.

Accept H_1:

The results have indicated that P (1, 2, 12 and 13) were all recorded as NAP repeatedly on all case studies. Therefore, the null hypothesis is now rejected and then the study concludes that some principles of bioclimatic design were uncommon to designers in the area. The researcher now overemphasise on the use of these uncommon principles by designers in the design concepts postulated at the end of chapter 2.

4.2 Thesis Research Field Studies

To establish a relationship between the Indoor thermal conditions and the adequacy of Bioclimatic Responses on buildings located in the study area, Faculty of Sciences, Yobe State University Damaturu was selected as the third case study within the hot dry climate of north-eastern states of Nigeria. Within this faculty building, three other case study buildings were selected for field studies: Lecture Hall building (100 seats), Classroom building (50 seats) and Laboratory building (50 seats) respectively. The three field study buildings within the faculty of sciences in Yobe State University are shown in Figure 4.5 below.

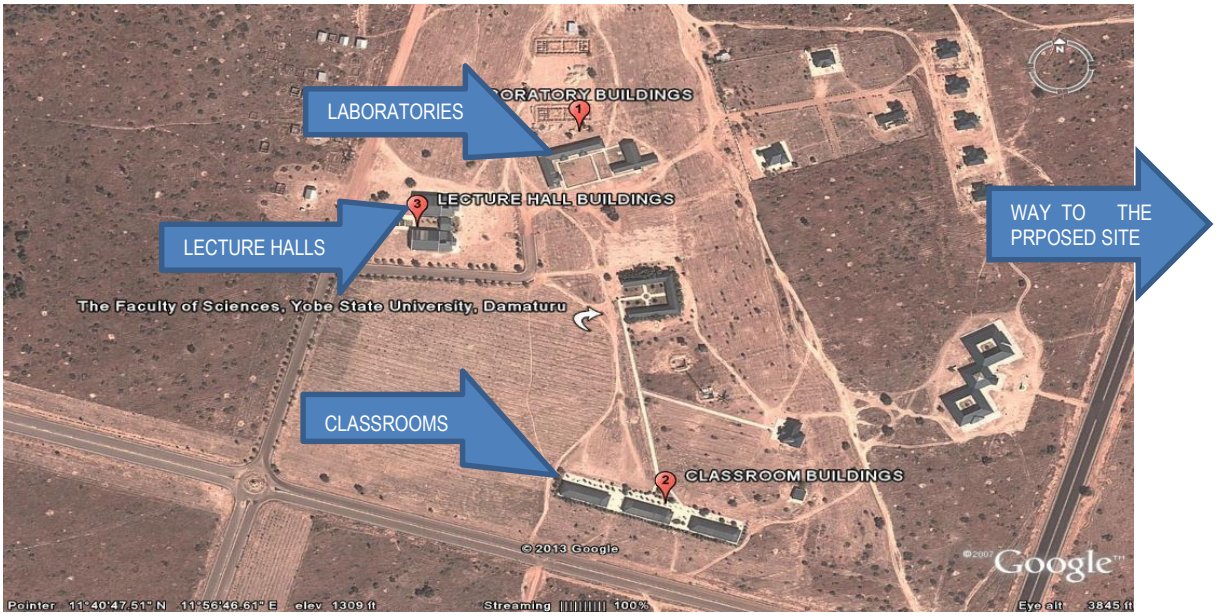


Figure 4.5: Field study buildings in the Faculty of Sciences YSU, Damaturu.
Source: Google earth search, 2014

4.2.1 Laboratory building complex

4.2.1.1 Bioclimatic response in design of laboratory (Day 1)

The principles of bioclimatic design for the area were applied such that out of the 22 numbers of applicable: there were 4 (AAP), 10 (IAP) and 8 (NAP) respectively (see sample checklist on Appendix I). Building is shown in Plate XI while the rates of implementation of principles on Fig 4.6


Plate X: Laboratory Building Complex (Chemistry Lab.)
Source: Researcher's Field Studies, 2014

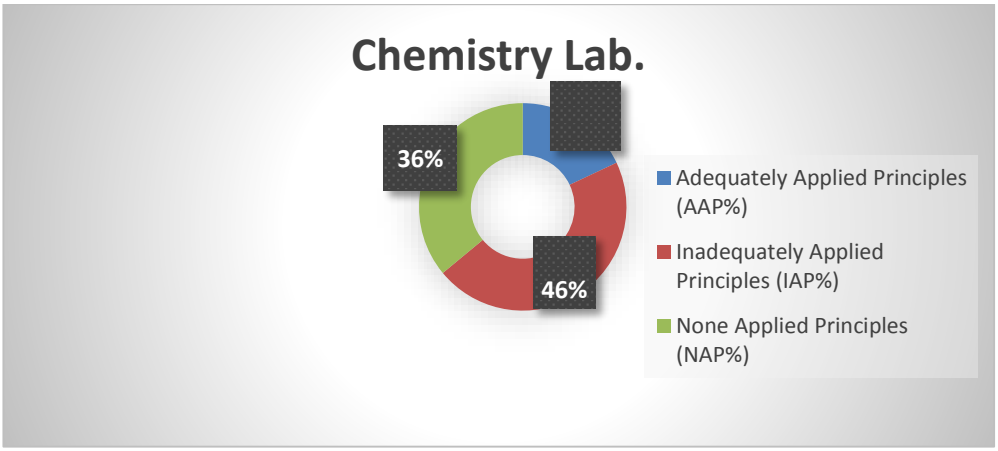


Figure 4.6: Bioclimatic Responses in Laboratory Building.
Source: Researcher's Field Studies, 2014

Figure 4.6 above presents the rates of bioclimatic responses with respect to the laboratory building: The percentage of adequately applied principles (AAP%) was 18%; the percentage of inadequately applied principles (IAP%) was 46% and the percentage of none applied principles (NAP%) was 36% respectively. This explains how only four (4) of the twenty-two (22) principles are adequately applied (minimised surface volume, insulative ceilings, white/light colours, and reflective surfaces) were used in the design of Laboratory building complex.

4.2.1.2 Physical Measurements on Indoor Thermal Variables (Day 1)

At the Laboratory building complex (Chemistry Lab.), the average values of thermal variables were obtained by instruments at the measuring points as shown on Figure 4.7 below.

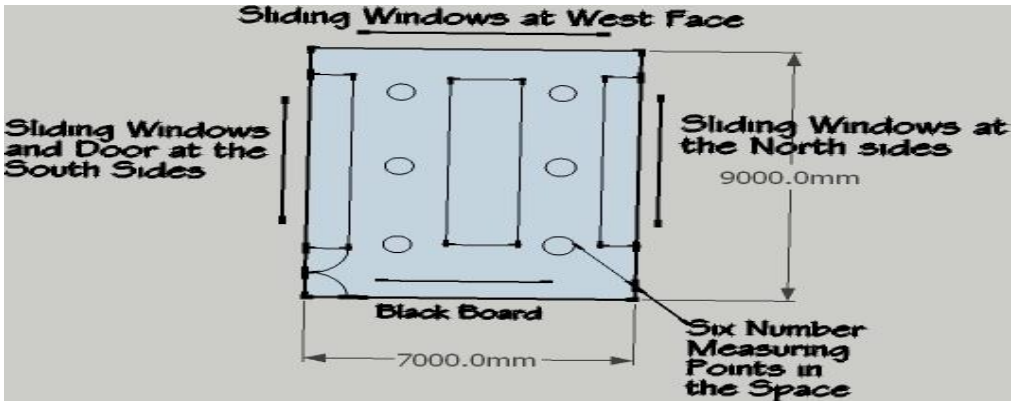


Figure 4.7: Six measuring points at the Chemistry Lab.
Source: Researcher's Sketches, 2014

As in Fig 4.7, all measurements were taken at the points or positions of holding the instruments as shown.

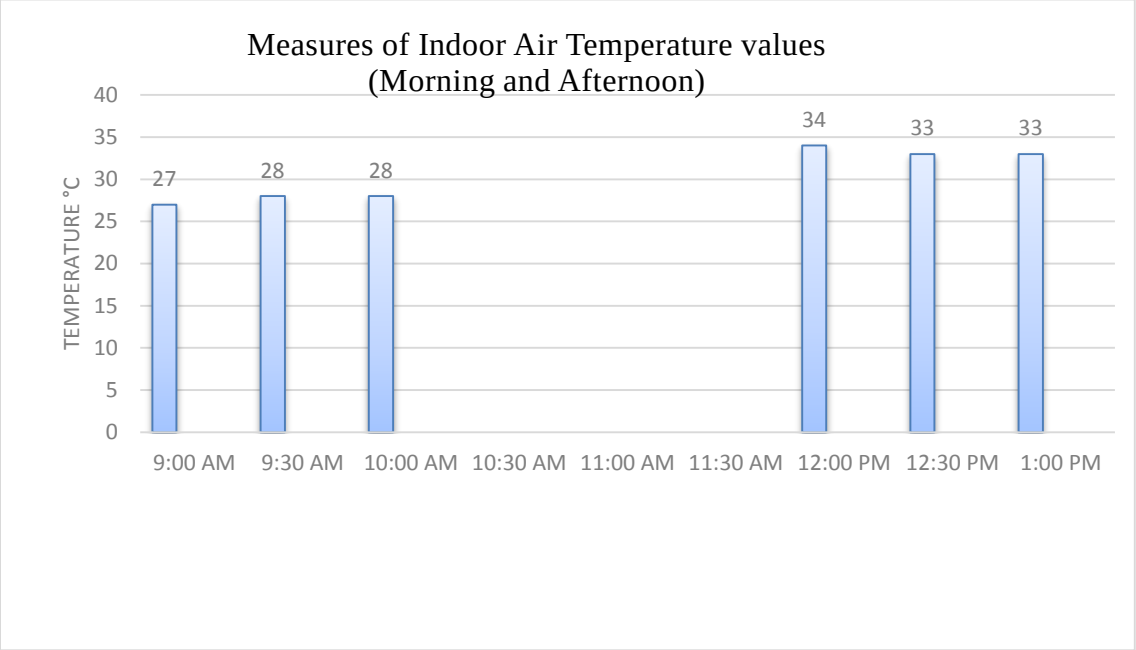


Figure 4.8: Indoor Air Temperature Measurements according to (pMm and pMa) at the Chemistry Lab. Day 1
Source: Researcher's Sketches, 2014

Fig 4.8 presents the values of measurements on air temperature: there was a gradual increase in the values in the morning session (27 – 28) ºC while there was a gradual decrease in the values in the afternoon session (34 – 33) ºC.

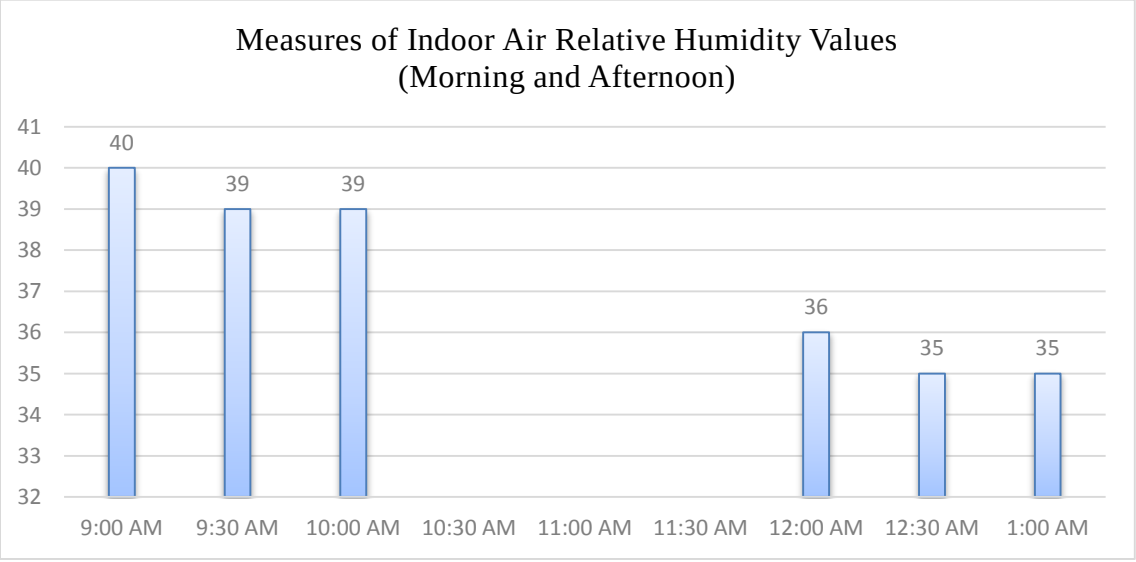


Figure 4.9: Indoor Air Relative Humidity Measurements according to (pMm and pMa) at the Chemistry Lab. Day 1
Source: Researcher's Sketches, 2014

Fig 4.9 presents the values of measurements on air relative humidity: there was a gradual decrease in the morning session (40 – 39) RH% as well as in the afternoon session (36 – 35) RH%.

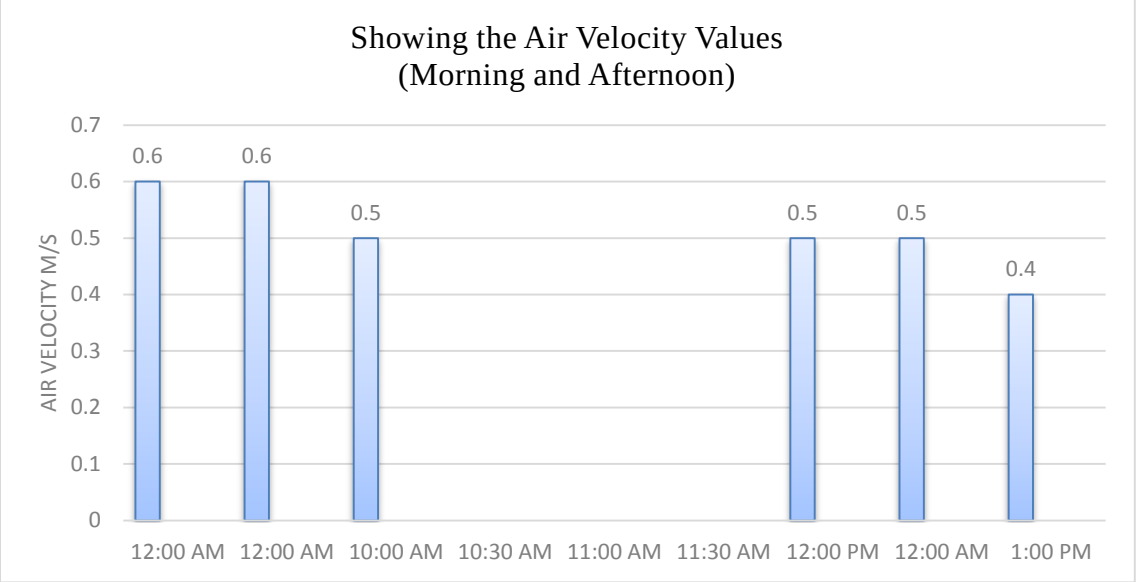


Figure 4.10: Indoor Air Velocity Measurements according to (pMm and pMa) at the Chemistry Lab. Day 1
Source: Researcher's Sketches, 2014

Fig 4.10 presents the values of measurements on air velocity: there was a negligible increase in the values in the morning session (0.6 – 0.5) m/s as well as in the afternoon session (0.5 – 0.4) m/s.

4.2.1.3 Subjective Assessments on Indoor Thermal Variables (Day 1)

The subjective assessments on thermal variables at the Chemistry Lab. were administered to the building occupants as shown in Plate XII



Plate XI: Questionnaire survey conducted at Chemistry Lab., Day 1.
Source: Researcher's Field Studies, 2014

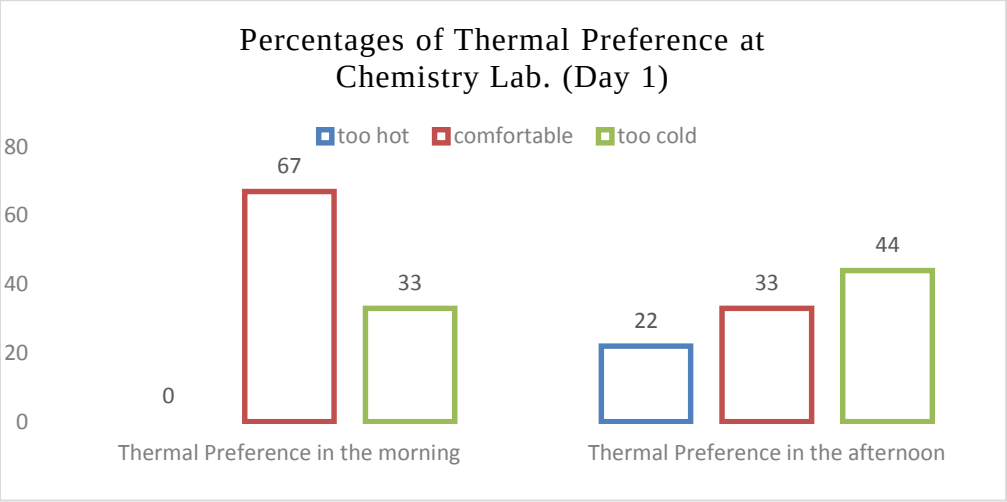


Figure 4.11: Thermal preferences (sMm and sMa) at Chemistry Lab.
Source: Researcher's Field Studies, 2014

Figure 4.11 presents the respondent's preference to indoor temperature (Day 1): In the morning, **67%** of respondents preferred the thermal condition of **27.7°C** temperature; whereas in the afternoon, **44%** of respondents preferred **lower** temperature values than the measured **33.3°C**. This means that the majority of respondents could be thermally alright up to the temperature of **30°C**in this building.

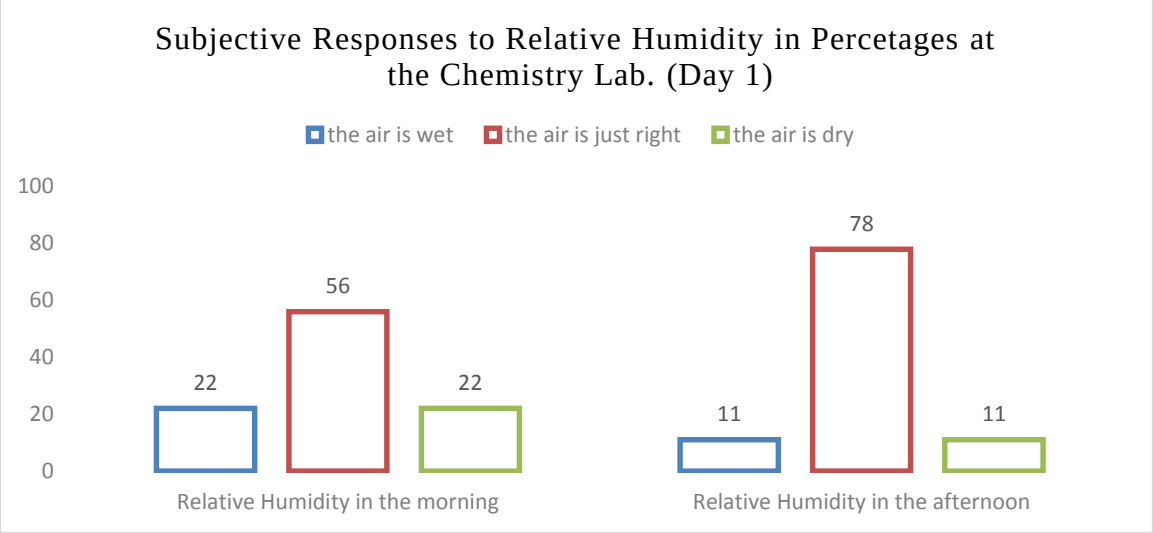


Figure 4.12: Subjective Responses to indoor relative humidity at Chemistry Lab.
Source: - Researcher's Field Studies, 2014

Figure 4.12 presents the respondent's votes to indoor relative humidity (RH) in Day 1 as follows: In the morning, **56%** of respondents preferred the measured RH value of **27.7%**; also in the afternoon, **78%** of respondents preferred the measured RH value of **26%**; This

means that the majority of the respondents were not comfortable with the RH values **higher than 27.7%** as measured in this building.

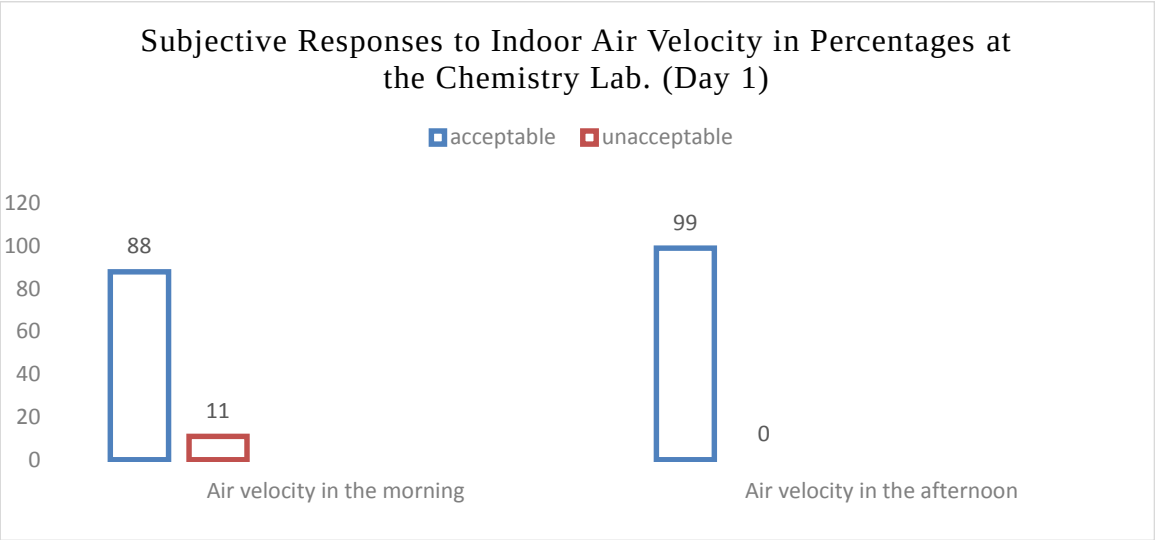


Figure 4.13: Subjective Responses on indoor air velocity at the Chemistry Lab.
Source: Researcher's Field Studies, 2014

Figure 4.13 presents the respondents' acceptability or unacceptability to indoor air velocity in Day 1: **88%** of respondents were comfortable with the air velocity value of **0.57m/s** as physically measured in the morning; whereas **99%** of respondents were comfortable with the air velocity value of **0.47m/s** as physically measured in the afternoon. This means that the majority of the respondents were comfortable with the values of air velocity ranging from ±**0.47m/s** to ±**0.57m/s** as measured in this building.

4.2.2 Classroom building complex

4.2.2.1 Bioclimatic response in design of classroom (Day 2)

The principles of bioclimatic design for the area were applied such that out of the 22 numbers of applicable: there were 6 (AAP), 7 (IAP) and 9 (NAP) respectively (see sample checklist on Appendix I). Building is shown in Plate XIII while the rates of implementation of principles on Fig 4.14



Plate XII: Classroom Building Complex (Physics Class)
Source: Researcher's Field Studies, 2014

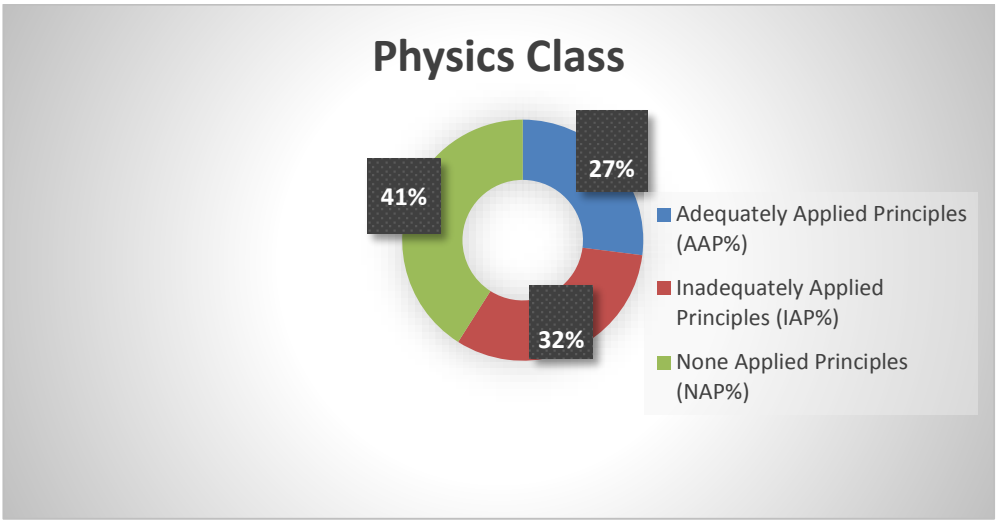


Figure 4.14: Bioclimatic Responses in Classroom Building.
Source: Researcher's Field Studies, 2014

Figure 4.14 above presented the rates of bioclimatic responses with respect to the laboratory building is such that: The percentage of adequately applied principles (AAP%) was 27%; the percentage of inadequately applied principles (IAP%) was 32% and the percentage of none applied principles (NAP%) was 41% respectively. This explains how only four (6) of the twenty-two (22) principles are adequately applied (minimised surface volume, insulative ceilings, correct orientations, more openings on NS directions, white/light colours, and reflective surfaces) were used in the design of Laboratory building complex.

4.2.2.2 Physical Measurements on Indoor Thermal Variables (Day 2)

At the Classroom building complex (Physics Class), the average values of thermal variables were obtained by instruments at the measuring points as shown on Figure 4.15 below.

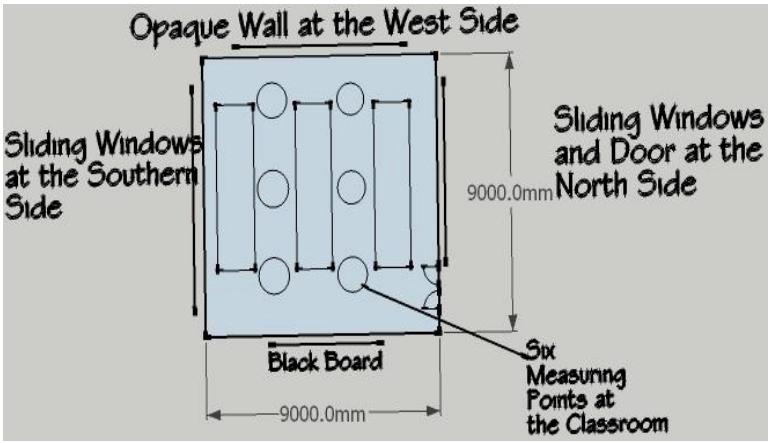


Figure 4.15: Six measuring points at the Physic Class.
Source: Researcher's Sketches, 2014

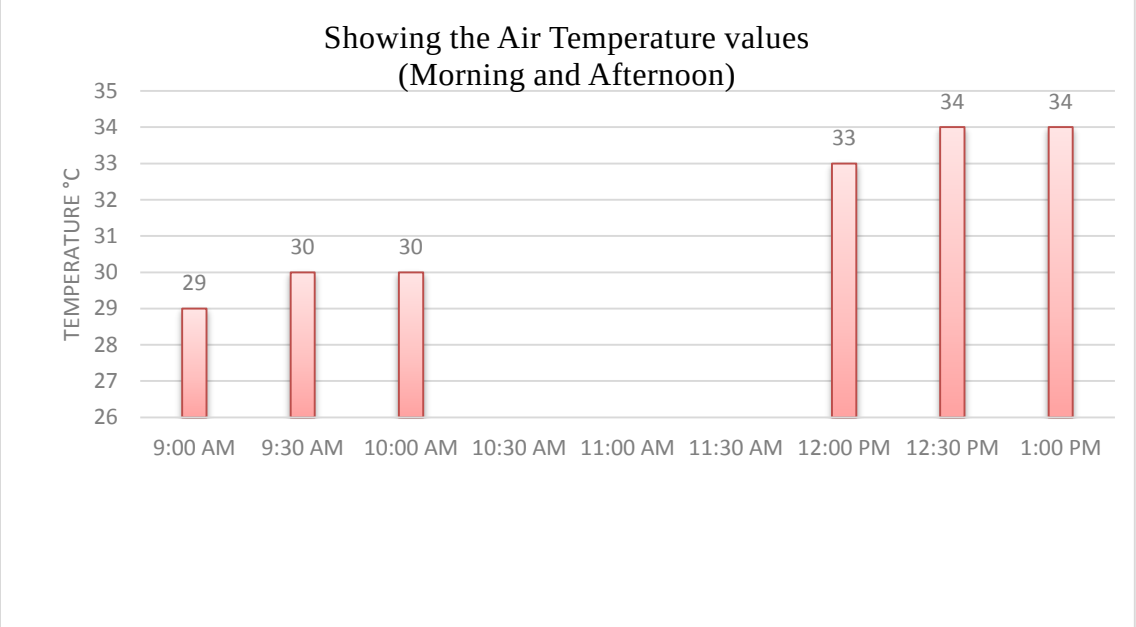


Figure 4.16: Indoor Air Temperature Measurements according to (pMm and pMa)) at the Physic Class. Day 2
Source: Researcher's Sketches, 2014

Fig 4.16 presents the values of measurements on air temperature: there was a gradual increase in the values in the morning session (29 – 30) ºC as well in the afternoon session (33 – 34) ºC.

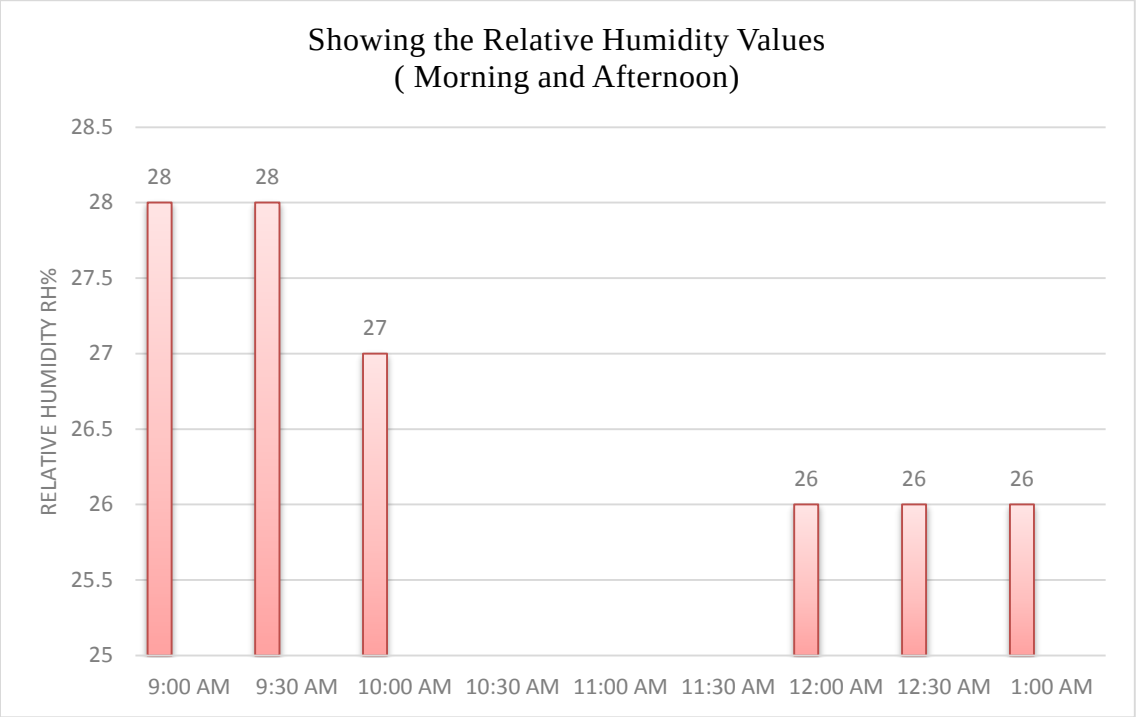


Figure 4.17: Indoor Air Relative Humidity Measurements according to (pMm and pMa) at the Physic Class. Day 2
Source: Researcher's Sketches, 2014

Fig 4.17 presents the values of measurements on air relative humidity: there was a gradual decrease in the morning session (28 – 27) RH% while there was a relatively uniform values in the afternoon session (26 – 26) RH%.

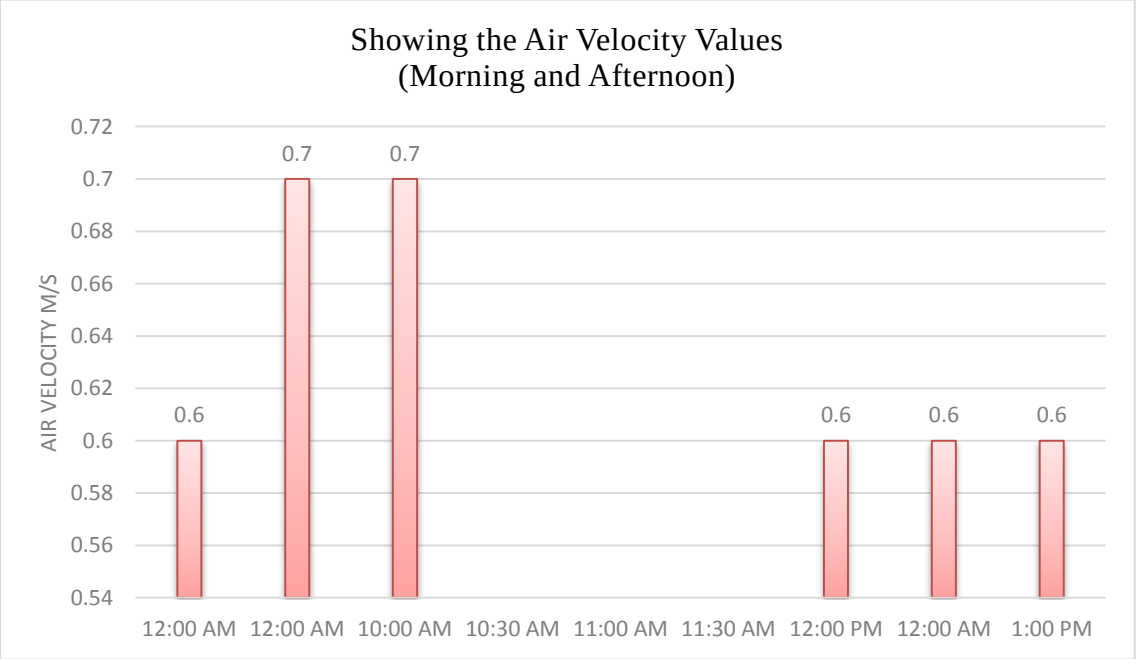


Figure 4.18: Indoor Air Velocity Measurements according to (pMm and pMa) at the Physic Class. Day 2
Source: Researcher's Sketches, 2014

Fig 4.18 presents the values of measurements on air velocity: there was a slight increase in the values in the morning session (0.6 – 0.7) m/s while there was a relatively uniform speed in the afternoon session (0.6 – 0.6) m/s.

4.2.2.3 Subjective Assessments on Indoor Thermal Variables (Day 2)

The subjective assessments questionnaires on thermal variables at the Physic Class Day 2 were administered to the building occupants as shown in Plate XIV



Plate XIII: Questionnaire survey conducted at Classroom, Day 2.
Source: - Researcher's Field Studies, 2014

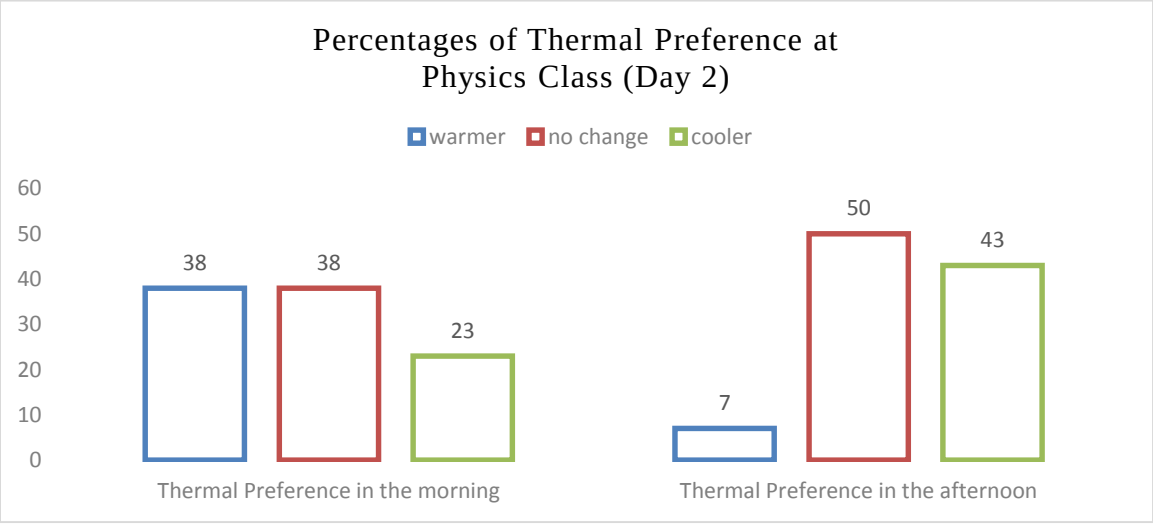


Figure 4.19: Subjective Responses to thermal preferences (sMm and sMa) at the Physics Class.
Source: Researcher's Field Studies, 2014

Figure 4.19 presents the respondent's preference to indoor temperature (Day 2): In the morning, **38%** of respondents preferred the thermal condition of **29.7°C** temperature, also

38% of respondents preferred **higher** temperature values than the measured **29.7°C**; whereas in the afternoon, **50%** of respondents preferred the thermal conditions at **33.7°C**. This means that the majority of respondents could be thermally alright up to the temperature of **33.7°C**in this building.

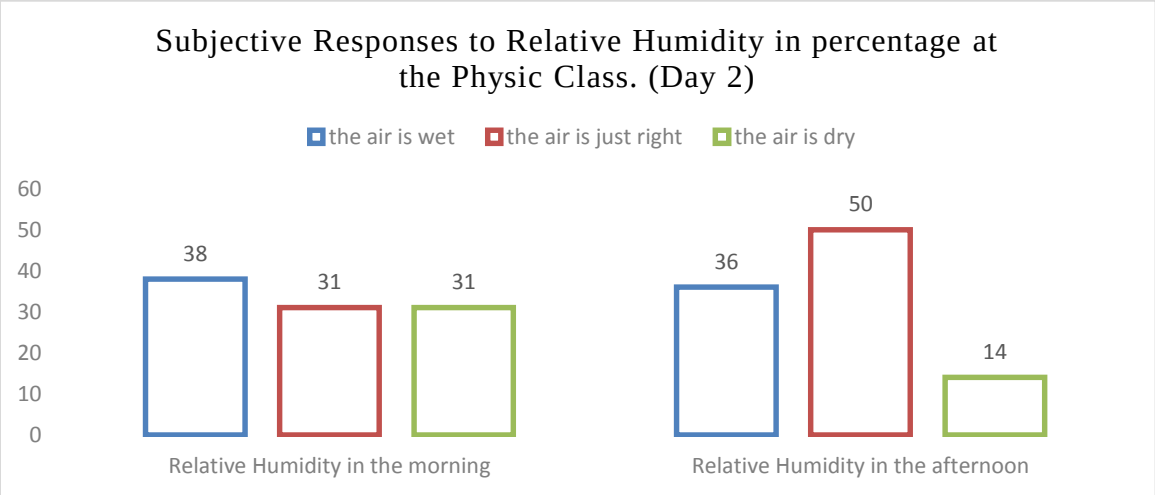


Figure 4.20: Subjective Responses to air relative humidity at Physics Class.
Source: Researcher's Field Studies, 2014

Figure 4.20 presents the respondent's votes to indoor relative humidity (RH) in Day 2 as follows: In the morning, **38%** of respondents preferred **lower** RH value than the measured **39.3%**; whereas in the afternoon, **50%** of respondents preferred the RH value of **35.3%** as measured; This means that the majority of the respondents were not comfortable with the RH values **higher than 35.3%** as measured in this building.

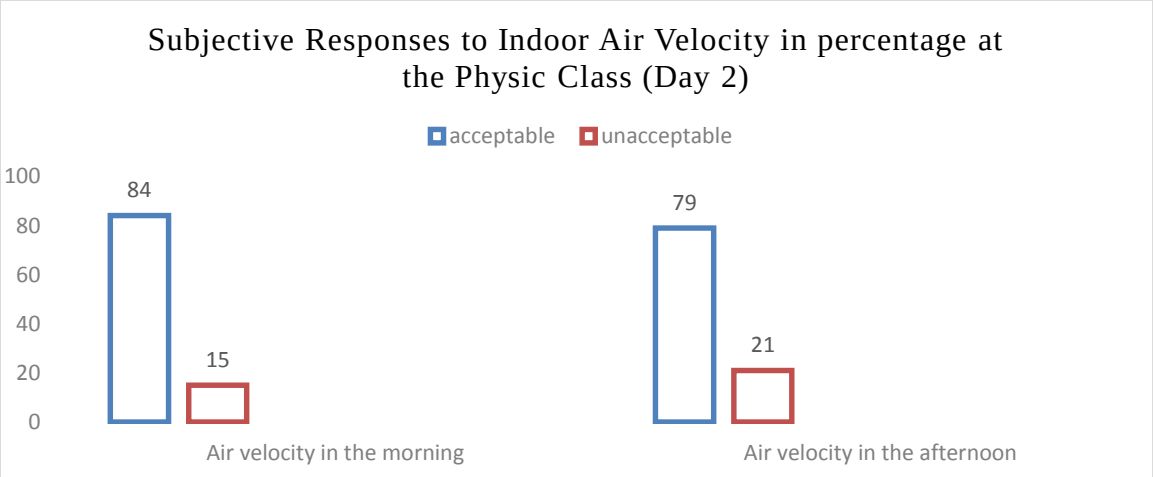


Figure 4.21: Subjective Responses on indoor air velocity at the Physics Class.
Source: Researcher's Field Studies, 2014

Figure 4.21 presents the respondents' acceptability or unacceptability to indoor air velocity in Day 2: **84%** of respondents were comfortable with the air velocity value of **0.67m/s** as physically measured in the morning; whereas **79%** of respondents were comfortable with the air velocity value of **0.6m/s** as physically measured in the afternoon. This means that the majority of the respondents were comfortable with the values of air velocity ranging from ±**0.6m/s** to ±**0.67m/s** as measured in this building.

4.2.3 Lecture hall building complex

4.2.3.1 Bioclimatic response in design of lecture hall (Day 3)

The principles of bioclimatic design for the area were applied such that out of the 22 numbers of applicable: there were 9 (AAP), 6 (IAP) and 7 (NAP) respectively (see sample checklist on Appendix I). Building is shown in Plate XV while the rates of implementation of principles on Fig 4.22



Plate XIV: Lecture Hall building Complex (Hall A)
Source: - Researcher's Field Studies, 2014

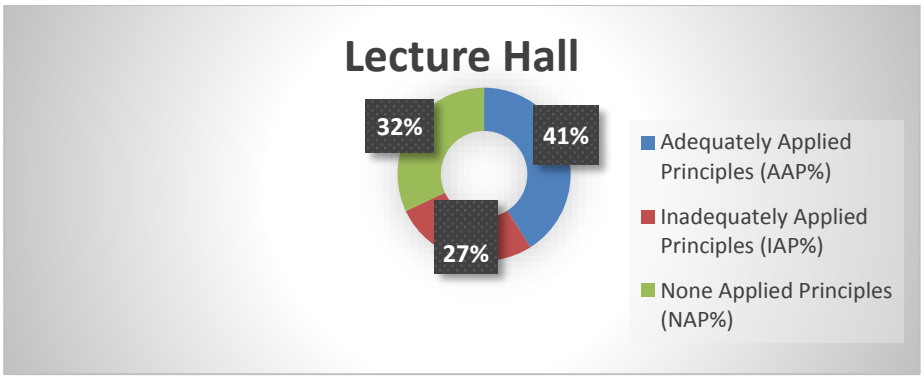


Figure 4.22: Bioclimatic Responses in Lecture Hall Building.
Source: Researcher's Field Studies, 2014

Figure 4.22 above presented the rates of bioclimatic responses with respect to the laboratory building is such that: The percentage of adequately applied principles (AAP%) was 41%; the percentage of inadequately applied principles (IAP%) was 27% and the percentage of none applied principles (NAP%) was 32% respectively. This explains how only nine (9) of the twenty-two (22) principles are adequately applied (mutual shades, facades protections, open space as heat sink, correct orientations, flat/vaulted roofing, more openings on NS directions, use of white/light colours, reflective surfaces and landscape plants) were used in the design of Laboratory building complex.

4.2.3.2 Physical Measurements on Indoor Thermal Variables (Day 3)

at the Lecture Hall building complex (Hall A), the average values of thermal variables were obtained by instruments at the measuring points as shown on Figure 4.23 below.

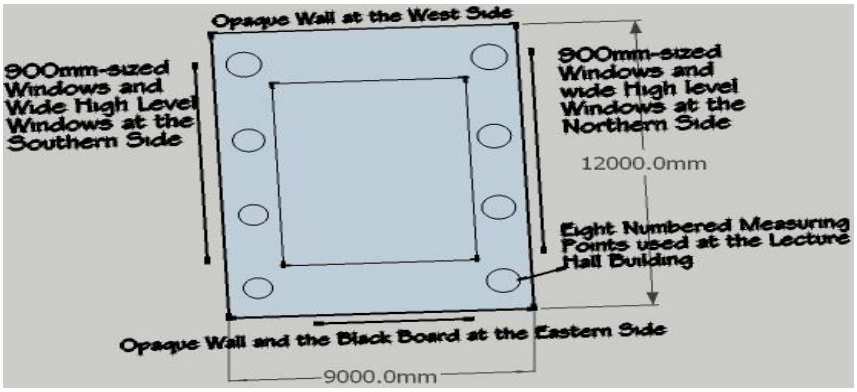


Figure 4.23: Eight measuring points at the Lecture Hall A.
Source: Researcher's Sketches, 2014

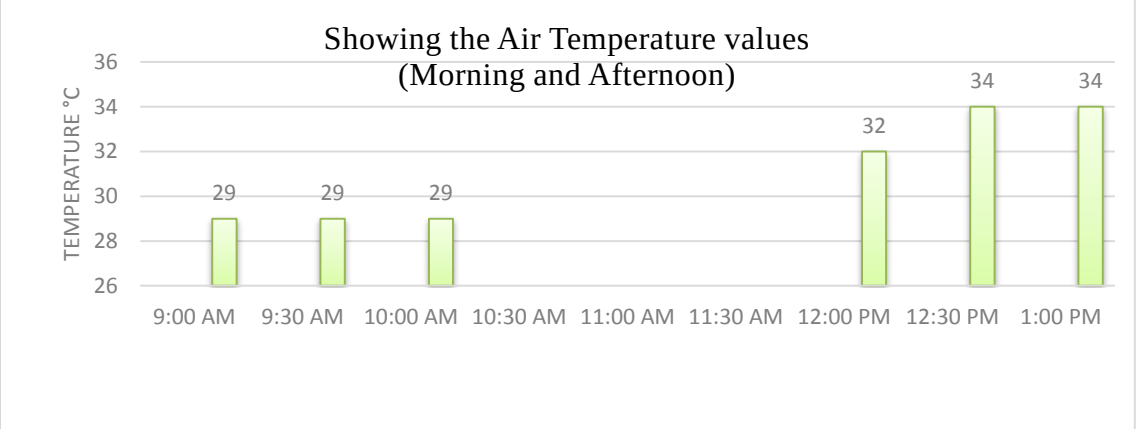


Figure 4.24: Indoor Air Temperature Measurements according to (pMm and pMa) at the Lecture Hall A. Day 3
Source: Researcher's Sketches, 2014

Fig 4.24 presents the values of measurements on air temperature: there was no change in values in the morning session (29 – 29) ºC while there was a gradual increase in values in the afternoon session (32 – 34) ºC.

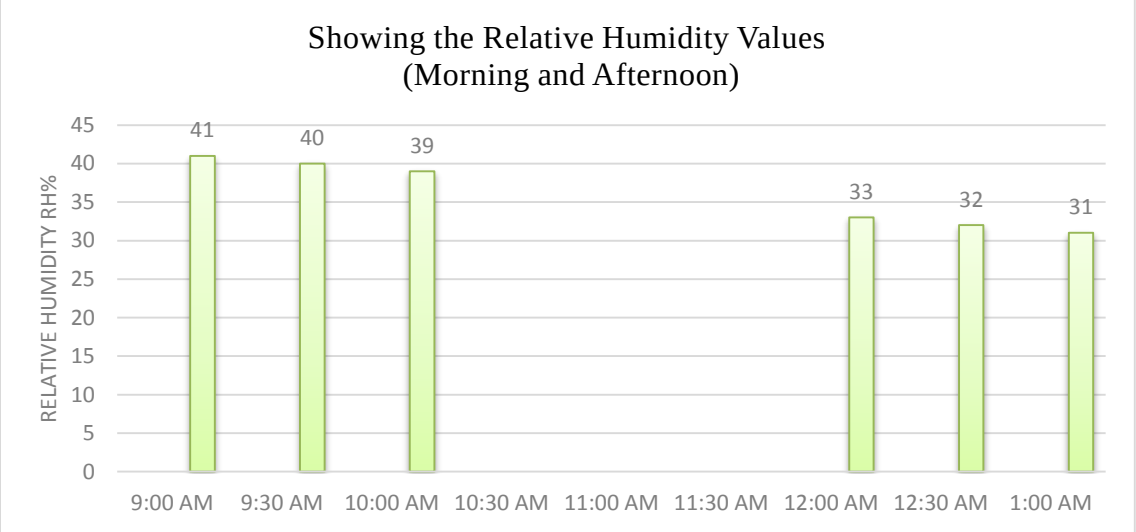


Figure 4.25: Indoor Air Relative Humidity Measurements according to (pMm and pMa) at the Lecture Hall A. Day 3
Source: Researcher's Sketches, 2014

Fig 4.25 presents the values of measurements on air relative humidity: there was a gradual decrease in the morning session (41 – 39) RH% as well as in the afternoon session (33 – 31) RH%.

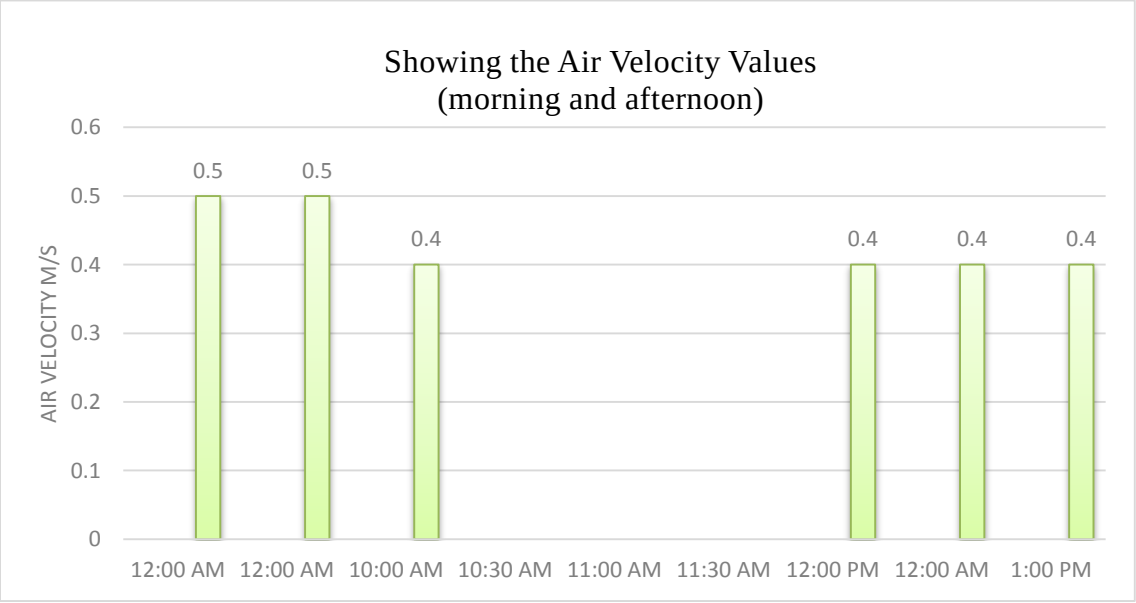


Figure 4.26: Indoor Air Velocity Measurements according to (pMm and pMa) at the Lecture Hall A. Day 3
Source: Researcher's Sketches, 2014

Fig 4.26 presents the values of measurements on air velocity: there was a slight increase in the values in the morning session (0.5 – 0.4) m/s while there was a relatively uniform speed in the afternoon session (0.64– 0.4) m/s.

4.2.3.3 Subjective Assessments on Indoor Thermal Variables (Day 3)

The subjective assessments questionnaires on thermal variables at the Lecture Hall A were administered to the building users as shown in Plate to the building occupants as shown in Plate XVI



Plate XV: Questionnaire survey conducted at Lecture hall, Day 3.
Source: Researcher's Field Studies, 2014

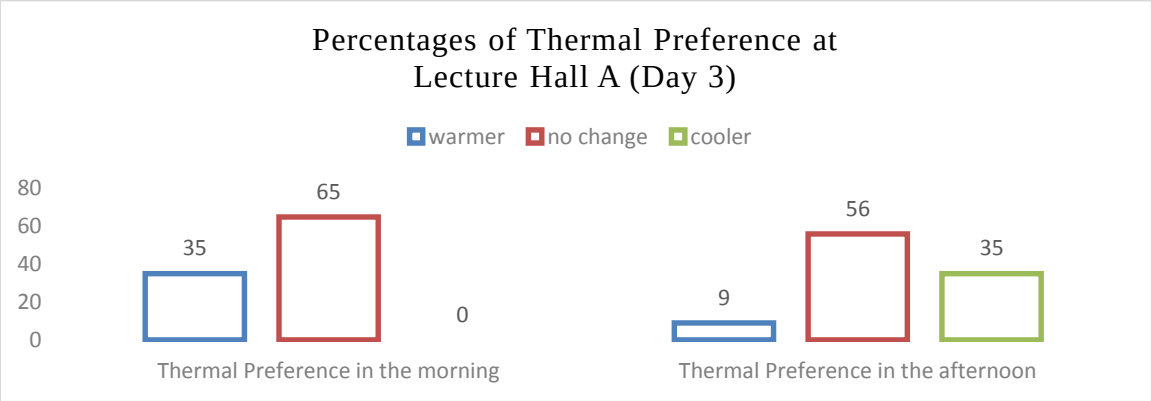


Figure 4.27: Subjective Responses to thermal preferences (sMm and sMa) at the Lecture Hall.
Source: Researcher's Field Studies, 2014

Figure 4.27 presents the respondent's preference to indoor temperature (Day 3): In the morning, **65%** of respondents preferred the thermal condition at **29°C** temperature; whereas in the afternoon, **56%** of respondents preferred the thermal condition at **33.3°C**.

This means that the majority of respondents could be thermally alright up to the temperature of **33.3°C**in this building.

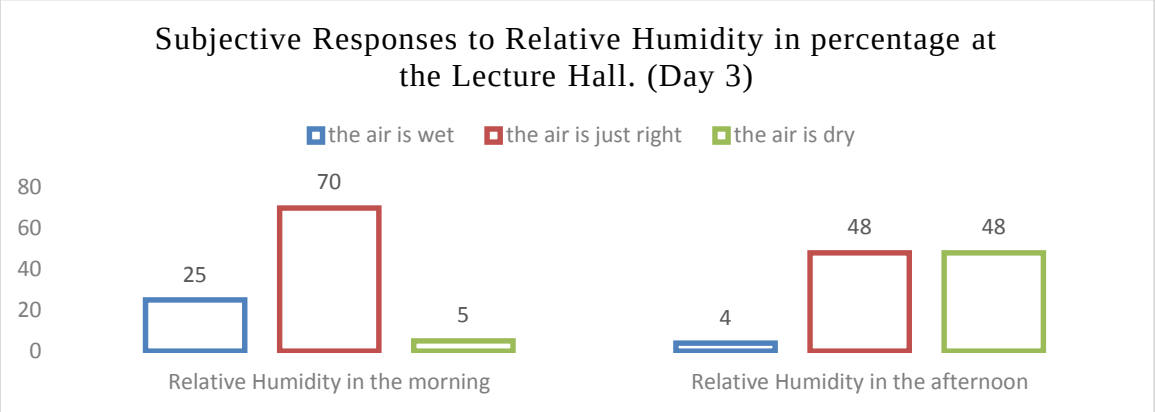


Figure 4.28: Subjective Responses to air relative humidity at the Lecture Hall A.
Source: Researcher's Field Studies, 2014

Figure 4.28 presents the respondent's votes to indoor relative humidity (RH) in Day 3 as follows: In the morning, **70%** of respondents were comfortable at the RH value of **40%** as measured; whereas in the afternoon, **48%** of respondents were comfortable at the RH value of **32%** as measured also **48%** of the respondents preferred **higher** RH value than the **32%** as measured. This means that the majority of the respondents were not co

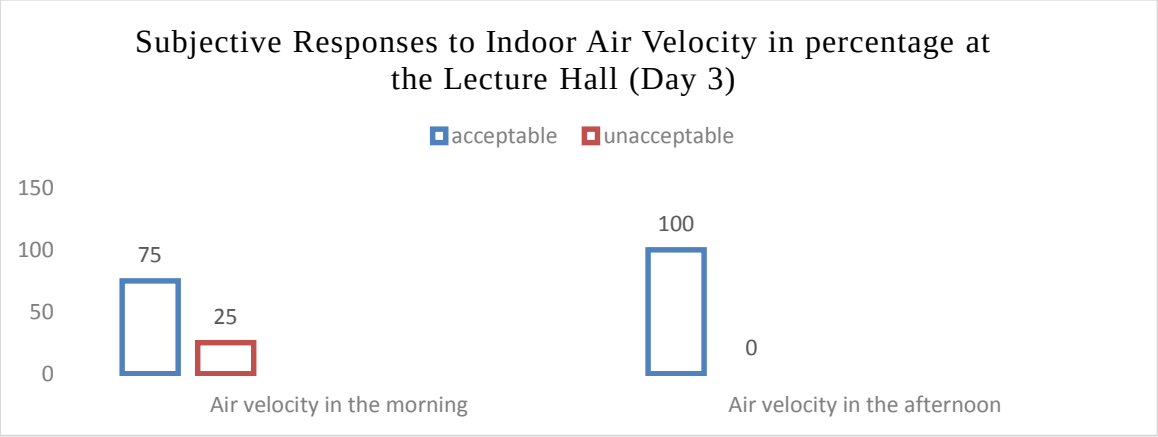


Figure 4.29: Subjective Responses on indoor air velocity at the Lecture Hall.
Source: Researcher's Field Studies, 2014

Figure 4.29 presented the respondents' acceptability or unacceptability to indoor air velocity in Day 3: **75%** of respondents were comfortable with the air velocity value of **0.47m/s** as physically measured in the morning; whereas **100%** of respondents were comfortable with the air velocity value of **0.4m/s** as physically measured in the afternoon.

This means that the majority of the respondents were comfortable with the values of air velocity ranging from ±**0.4m/s** to ±**0.47m/s** as measured in this building.

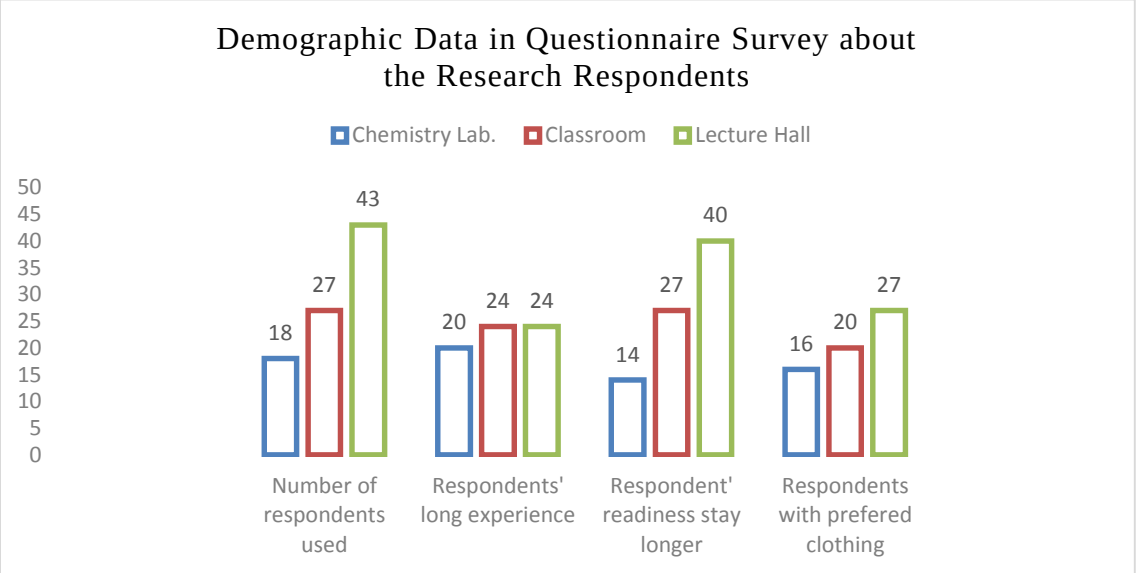


Figure 4.30: Respondents' basic data as used in the Questionnaire Survey.

Source: Researcher's Field Studies, 2014

Fig 4.30 presents the information that was kept to help researcher in the discussions.

4.2.4 Results and discussions

4.2.4.1 Field study results

1. Based on the above presentations about the bioclimatic responses and the indoor thermal conditions in the study area, bioclimatic responses of the three field study buildings were recorded and converted into percentages of the three scales (AAPn%), (IAPn%) and (NAPn%).

Table 4.2 Bioclimatic Responses Assessed on the three Field Studies buildings.

S/No.	Laboratory Building Complex (Day 10)	Classroom Building Complex (Day 2)	Lecture-Hall Building Complex (Day 3)
Percentages of Adequately Applied Principles (AAP%)	18%	27%	41%
Percentages of Inadequately Applied Principles (IAP%)	45%	32%	27%
Percentages of None Applied Principles (NAP%)	36%	41%	32%

Source: Researcher's Analysis, 2014

It now follows from Table 4.2 above that the **Adequately Applied** (AAP) principles of bioclimatic design were applied as variously as possible in the design of the three buildings:

i. **41%** in the design of Lecture Hall building,

ii. **27%** in the design of Laboratory building and then

iii. **18%** in the design of Classroom building.

2. The synchronized measurements on these buildings showed not any value of Temperature and Relative Humidity satisfied up to 80% respondents according to the comfort votes: See below for the findings of the subjective measurements on comfort v

Table 4.3 Synchronized measurements (pM and sM) on thermal variables at Field Studies.

Table 4.3 Thermal comfort Assessed on the three Field Studies buildings.

Variables' of thermal comfort		Laboratory Building Complex		Classroom Building Complex		Lecture-Hall Building Complex		Average Value of Comfort Votes in all cases	Values of Dis-comfort in all cases
		m	a	m	a	m	a		
Indoor Air Temp. (ºC) Or (%)	pM	27.7	30	29.7	33.7	29	33.3	31ºC	31ºC
	sM	67	44	38	50	65	56	53%	47%
Indoor Air Relative Humidity (RH %)	pM	27.7	26	35.3	35.3	40	32	33RH%	33RH%
	sM	56	78	38	50	70	48	57%	43%
Indoor Air Velocity m/s	pM	±0.57	±0.47	±0.67	±0.6	±0.47	±0.4	\ 0.53m/s	0.53m/s
	sM	88	99	84	79	75	100	88%	12%

Source: Researcher's Analysis, 2014

Comfort Zone is attained at range of combined temperature and humidity with up to 80% comfort votes for the majority of people using the indoor space. From Table 4.3 none of

the values of respondents' comfort votes (with respect to indoor air temperature and indoor air relative humidity) attained the percentage of 80%.

4.2.4.2 Discussions

Based on the records of about 40% highest use of **adequately applied principles** (AAP) in design of the three field study buildings, the indoor thermal discomfort in the area about the following variables is thus:-

Indoor air temperature measurements;

A. At the Lecture-hall building, Day 3, where the (AAP) % was 41%:

   i. **35%** of indoor users were uncomfortable with the **29ºC** temperature measurements in the morning session, and

   ii. **44%** of indoor users were also uncomfortable with the **33.3ºC** temperature measurements in the afternoon session.

   It is now clearly indicated that the comfort votes was not up to the 80% standard in the indoor conditions of this building.

B. At the Laboratory building, Day 1, where the (AAP) % was 27%:

   iii. **33%** of indoor users were uncomfortable with the **27.7ºC** temperature measurements in the morning session, and

   iv. **56%** of indoor users were also uncomfortable with the **30ºC** temperature measurements in the afternoon session.

C. At the Classroom building, Day 2, where the (AAP) % was 18%:

   v. **62%** of indoor users were uncomfortable with the **29.7ºC** temperature measurements in the morning session, and

   vi. **50%** of indoor users were also uncomfortable with the **33.7ºC** temperature measurements in the afternoon session.

Indoor air relative humidity measurements:

D. At the Lecture-hall building, Day 3, where the (AAP) % was 41%:

vii. **30%** of indoor users were uncomfortable with the **40RH** relative humidity of indoor air measurements in the morning session, and

viii. **52%** of indoor users were also uncomfortable with the **32RH** relative humidity of indoor air measurements in the afternoon session.

E. At the Laboratory building, Day 1, where the (AAP) % was 27%:

ix. **44%** of indoor users were uncomfortable with the **27.7RH** relative humidity of indoor air measurements in the morning session, and

x. **22%** of indoor users were also uncomfortable with the **26RH** relative humidity of indoor air measurements in the afternoon session.

F. At the Classroom building, Day 2, where the (AAP) % was 18%:

xi. **62%** of indoor users were uncomfortable with the **35.3RH** relative humidity of indoor air measurements in the morning session, and

xii. **50%** of indoor users were also uncomfortable with the **35.3RH** relative humidity of indoor air measurements in the afternoon session.

4.2.5 Test of field studies results

4.2.5.1 Research statement

S_1 = there is a significant relationship between the adequacy of bioclimatic responses of a building and its indoor thermal comfort in hot dry areas.

S_o = there is no significant relationship between the adequacy of bioclimatic responses of a building and its indoor thermal comfort in hot dry areas.

Decision rule

Accept S_1: {if result of BDS about the value of AAP% < 50% = result of TCS on s(M) about the value of p(M) < 80% comfort votes}.

Reject S_o: if result of BDS about the value of AAP% > 50% = result of TCS on s(M) about the value of p(M) < 80% comfort votes}.

Field study results:

BDS (AAP) % = 40%

TCS p(M) on air temperature range of (27.7 – 33.7) ºC = s(M) 53%

p(M) air relative humidity range of (26 - 40) RH% = s(M) 57%

p(M) air velocity range of (0.4 – 0.67) m/s = s(M) 87%

The cross tabulation of relationship between bioclimatic design studies (BDS) and thermal comfort studies (TCS) showed that there is a significant relationship between the percentage of adequately applied principles (AAP)% of bioclimatic design and two of the three variables of thermal comfort (Temp. ºC, and RH %) while there is no significant relationship based on the value of indoor air velocity.

Accept H_1:

BDS (AAP) % = 40% < 50%;

TCS p(M) on air temperature range of (27.7 – 33.7) ºC = s(M) 53% < 80% comfort votes

p(M) air relative humidity range of (26 - 40) RH% = s(M) 57%< 80% comfort votes

p(M) air velocity range of (0.4 – 0.67) m/s = s(M) 87%> 80% comfort votes

The null statement is now rejected, and conclude that bioclimatic responses regulate buildings' indoor thermal discomforts when adequately applied in hot dry area.

5.0 CHAPTER FIVE: DESIGN REPORT

5.1 Site Information

The proposed site is located in Yobe State of Nigeria. Specifically, the site is located at the southern outskirt of the State Capital, Damaturu township master plan in Yobe State University along the Gujba road. The following are comprehensive features of the site.

Geography: -Yobe is among the six (6) states in one of the six (6) geopolitical zones in the country (Fig. 5.1). It is in the north-east zone and it is surrounded by other states: Borno towards the East, Gombe towards the South, Bauchi towards the West, Jigawa towards the North. It borders Diffa Region and Zinder Region to the north in the Republic of Niger. Because the state lies mainly in the dry savanna belt, the state is dry and hot for most months of the year except in the southern part of the state which has a milder climate. Its landscape is made up of plain or flat lands and desert sand in some areas for up to 300ft above the sea level.



Figure 5.1: Map of Nigeria showing Yobe State
Source**:** Nigeria Gallery Directory, 2014.

History: -Yobe State came into being on the 27 August, 1991. It was carved out of the old Borno State by the Babangida administration. Yobe State was created because the old Borno State was one of Nigeria's largest states in terms of land area and was therefore considered to be too large for easy administration and meaningful development. Ethnic rivalries within the old Borno State also contributed to the decision.

Local Government Areas: - It comprises of seventeen (17) local government councils (Fig. 5.2), in addition to Damaturu, the state capital. They are: Bursari, Fika, Nguru, Damaturu, Fune, Potiskum, Geidam, Jakusko, Tarmuwa, Bade, Karasuwa, Yunusari, Gujba, Machina, Yusufari, Gulani and Nangere.

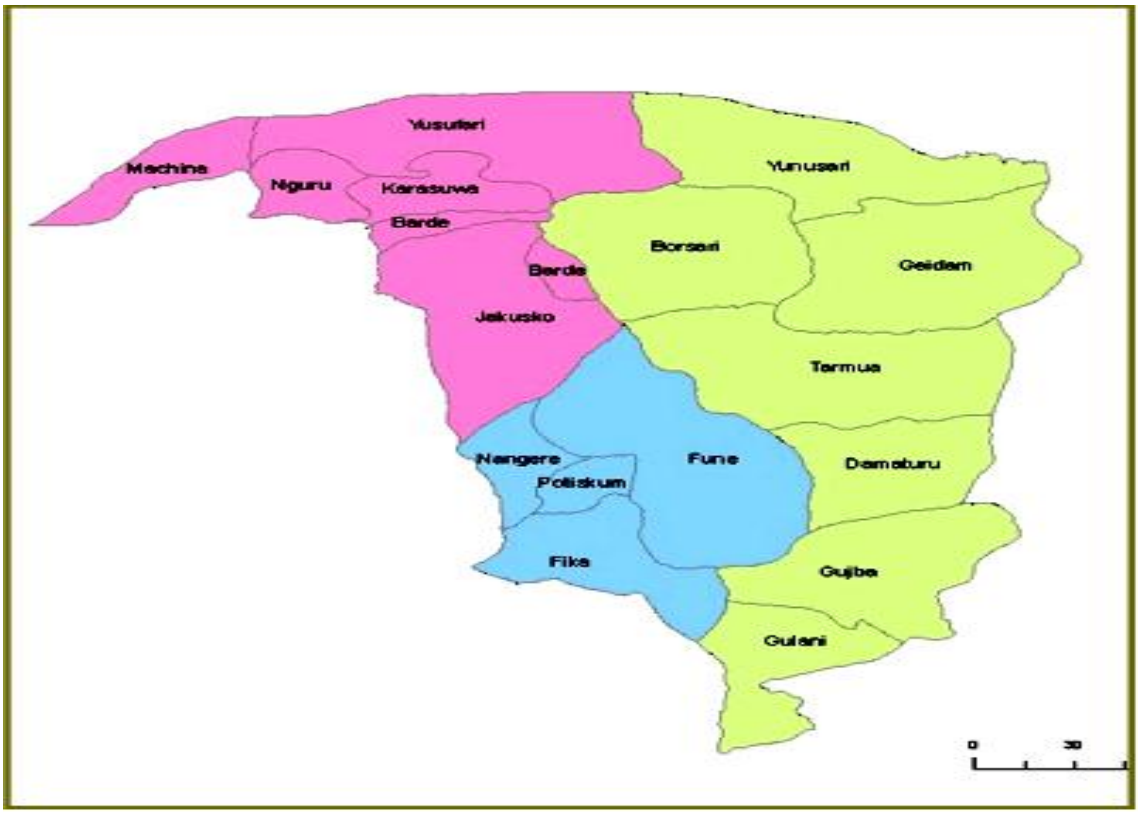


Figure 5.2: Map of Yobe State showing its seventeen (17) local government
Source**:** Nigeria Gallery Directory, 2014.

Economy: -While Yobe state is an agricultural state it also has rich fishing grounds and mineral deposits of gypsum, kaolin, and quartz in Fune. The state's agricultural products

include: gum arabic, groundnuts, beans, cotton, etc. The state is also said to have one of the largest cattle markets in West Africa located in Potiskum.

Demographics: -The major ethnic groups living in Yobe State are Fulani, Kanuri, Kare-Kare, Bolewa, Ngizim, Ngamo Bade, Hausa, and Shuwa.

Summary: - The proposed site for the project lies on the master plan of Damaturu city (Fig. 5.3), which is the capital city of Yobe State. The town is comprised of tribes such as: kanuri, ngamo, kare-kare, ngizim, bolewa, Fulani, bade, etc. Damaturu was created in the reign of Mai Ngazar-gamu of Kanem Borno Empire. Originally the site is on the master plan of Yobe State University (YSU) Damaturu, being a young institution, in that its land is generally virgin where the built-up area is yet less than ten (10%) percent of the total master plan size. Damaturu has an estimated population of about 1, 077, 942 from the 2015 registered voters figure. The coordinates of the city on world map is as follows: 11˚44˙40˝N 11˚57˙40˝E 11.74444˚N 11.96111˚E



Figure 5.3: Map of Damaturu and its Environment
Source**:** Google Earth Search, 2014.

5.1.1 Site selection

Seven different sites were reserved as the proposed sites for faculty buildings in the University (Fig. 5.4). The site for this project is hence restricted to anyone out of those reserved sites. After rigorous analysis based on some criteria for the selection then one site was finally selected.

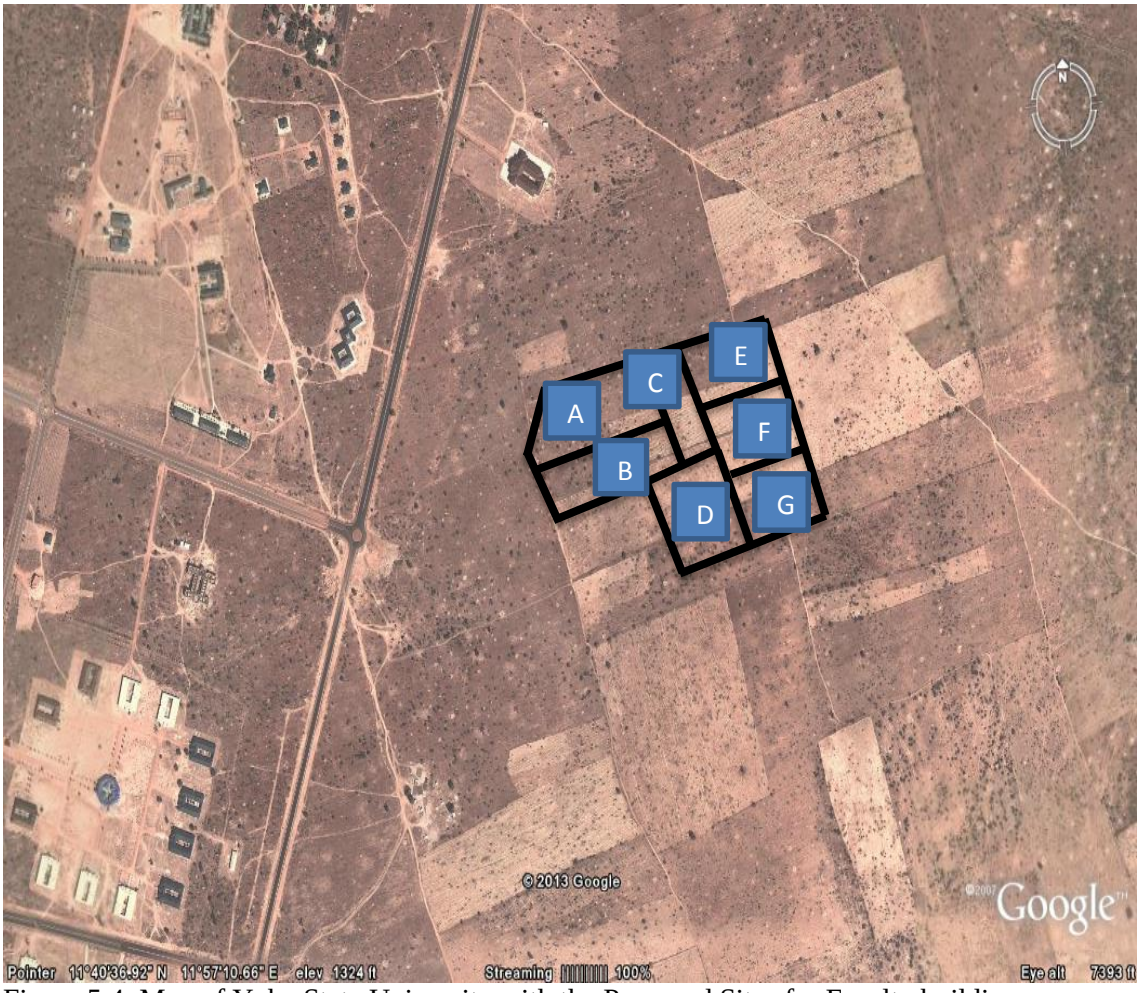


Figure 5.4: Map of Yobe State University with the Proposed Sites for Faculty buildings
Source**:** Google Earth Search, 2014.

5.1.2 Site selection criteria

Although many sites were ear-marked as sites for the proposed University Faculty Buildings, (Table. 5.1) some sets of criteria based on Environmental considerations has favoured site A's location as:-

1. The site is located within the central parts; as defined by the given sites on the master plan for all faculties.

2. The site is located within the academic core; not on the fringes of the approved master plan of the University.

3. The site is easily accessible for pedestrian and vehicles; this could be seen from the multiple of access road linked to other faculties and generally the University core.

Table 5.1 Priority of Site A in the Selection Criteria.

The Sites	Centrality of Site to other Facilities	Accessibility of Site Entrances	Position of Site at the Academic core	Total Scores
A	3	3	2	8
B	3	2	2	7
C	2	1	2	5
D	2	2	2	6
E	1	2	1	4
F	1	1	1	3
G	1	2	1	4

The selected site is spacious (47543m²) adequate to support the educational, recreational, parking, and other spaces and area requirements for the faculty. It is elongated along the east and west than all the other sites in the proposed faculty buildings. The N-S orientation could be quit harnessed.

5.2 Site Analysis

The site analysis follows the following steps: site features analysis (climatic conditions, site size, existing-buildings on site, noise protection, vegetation, topography and services) site shadow analysis and site zoning concepts on the site. Recommendations follows afterwards.

5.2.1 Site features analysis

1. Climate Conditions: - The climate of Damaturu, the capital of Yobe State is a typical of arid zones (hot dry conditions). Climatic conditions are described as follows.

   i. Temperature: - the site has a maximum temperature of forty-five degrees Celsius (45˚C) in the month of April and a minimum temperature of thirty degree Celsius (30˚C) in the month of August. The range is found to be fifteen degree Celsius (15˚C). By this range, the maximum and minimum of each month is found to be more or less different in value. See Fig. 5.5

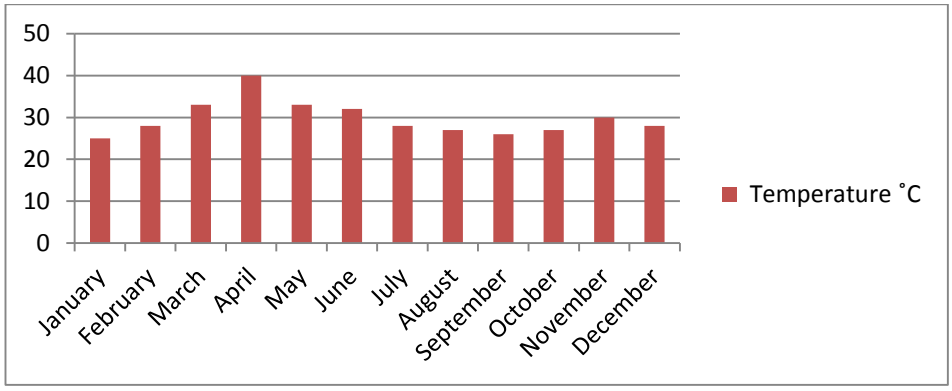


Figure 5.5: Average monthly temperature on site
Source**:** Damaturu meteorological station, 2014.

   ii. Humidity: High humidity levels of about 70% is attained during the rainy season. This drops down to about 20% during the dry season. The low humidity level and dry weather is the precursor of dry season also the departure of rainy season, where high humidity and hot weather symbolize

rainy season. The weather is marked by a high temperature and either dry-air (dry season) or moist-air (rainy season) in the atmosphere. See Fig. 5.6

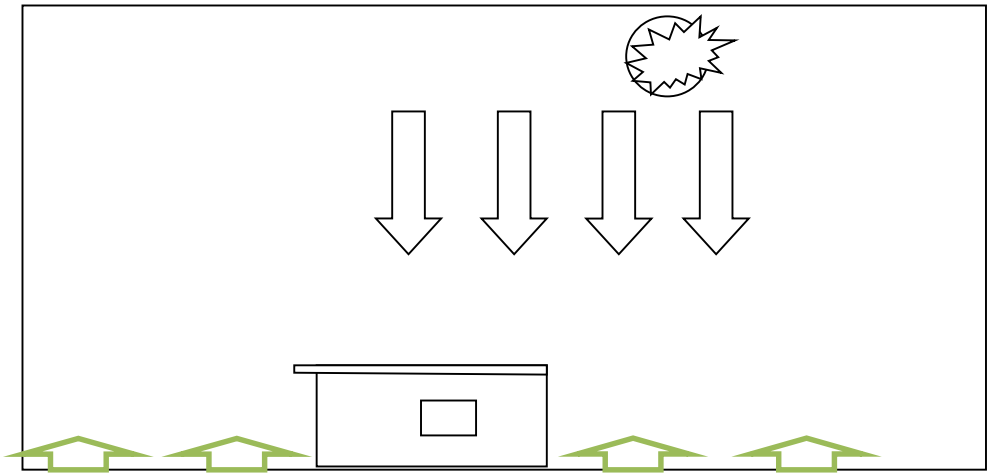


Figure 5.6: Relative humidity chart in the rainy season
Source**:** Damaturu meteorological station, 2014.

iii. Rainfall: Rainfall begins in the months of May - June and goes off in October; Damaturu is among the areas with least amount of rain in Nigeria (90 - 120 days). The approximate value for the site annual rainfall is eight hundred millimetres (800mm). The maximum rainfall is 286mm in the month of August while the minimum rainfall is 20mm in the month of May are recorded. The rain is accompanied with it windstorms especially at the beginning of the rainy season. The chart for annual rainfall is shown below. See Fig. 5.7

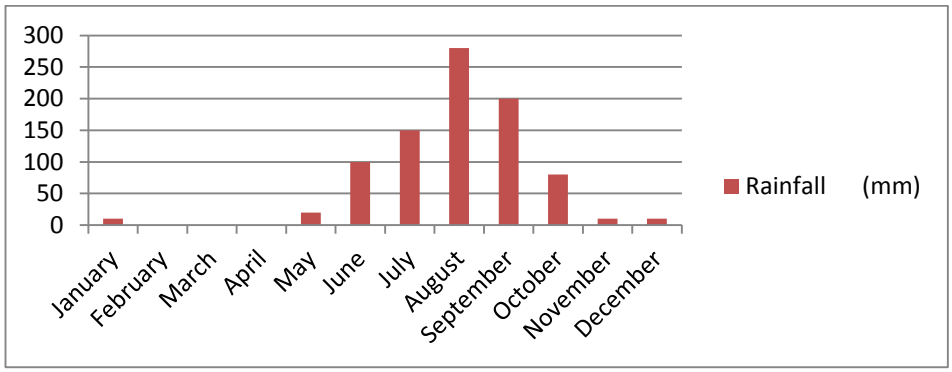


Figure 5.7: Annual rainfall chart
Source**:** Damaturu meteorological station, 2014.

iv. Wind: The two known trade winds (south-west and north-east) affects the site differently: north-east trade wind blows with heat and dust for 8 month while the south-west trade wind blows with moisture for 4 month in rainy season. The weather of any place depends very much on the nature of the winds that are blowing over it at any particular time, as they influence the area with their characteristics. The moisture-laden south-westerly winds which blow over Nigeria from April to September bring rainfall to the country. On the other hand, the cool dry and dusty conditions between December and February. See Fig. 5.8



Figure 5.8: North-east and south-west trade winds chart
Source**:** Damaturu meteorological station, 2014.

v. Sunshine and cloud cover: the sunshine is intense such that the glare causes sight malfunctions. The total hours of sunshine is increased during the dry season. The sunshine reaches up to 3200 hours in the extreme north-east Nigeria. The effect of sunshine in the site is highly considered because, the direct radiation of the sun during the day causes glare and heat on the land surfaces up to the stated temperature, whereas the direct radiation of the sun in harmattan is highly welcomed to comfort the adverse cold over the weather. The value of sunshine is given in terms of sunshine exposure in hours per day. Almost all the day hours is exposed to the sunshine. See Fig. 5.9

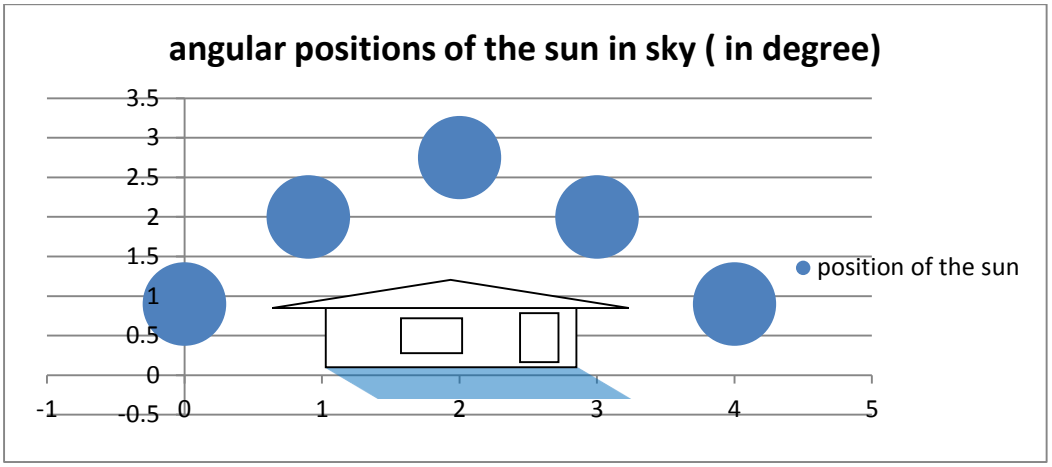


Figure 5.9: Positions of sun in the sky in Yobe.
Source**:** Damaturu meteorological station, 2014.

2. Site Size: - the site is spacious (47543m²) adequate to support the educational, recreational, parking, and other spaces and area requirements for the faculty. Site size aim is to ensure a good shaped site and the possibility for extension. The information on site size is feasible from (Fig. 5.10)

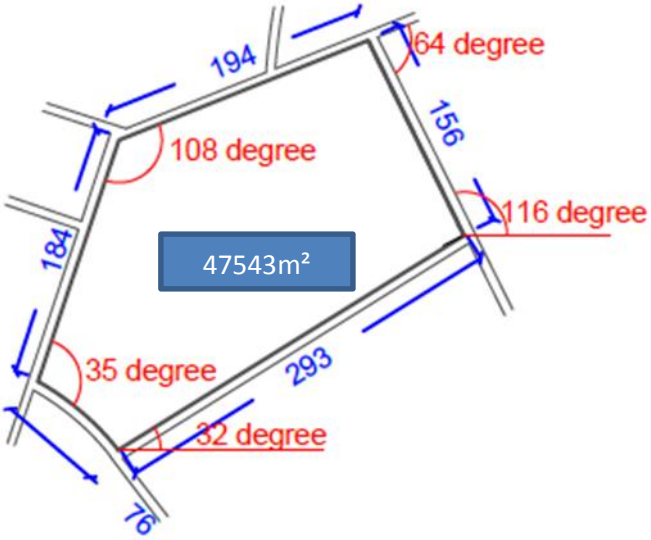


Figure 5.10: Total area or site size.
Source**:** Yobe State University physical planning unit, 2014

3. Existing buildings on Site: - the site is a virgin land, that is, no any existing building is observed on it. It is now suitable to position the proposed building at

the central part of the site. The central position allow for the design to overwhelm the whole site space.

4. Vegetation: - There is sparse trees, shrubs and grasses on the plain land of the site (Fig. 5.11). The predominant feature in the six to eight months of the dry season is baobab trees and barren land. Whereas a rapid and luxuriant plant growth for the four to six months is featured in wet season. The site is currently used as farm.



Figure 5.11: the site vegetation cover
Source**:** Researchers Field Studies, 2014.

5. Noise Protection: - The site is a quiet environment due to the absence of traffic and other noisy activities around it that could generate noise. Although the distance from other facilities in the campus is not far but the noise protection on site is feasible.

6. Topography: - The site is relatively flat as in above (Fig. 5.11). No flooding issues is recorded on site therefore it could easily support works such as fountains. The use of buffer trees, site clearance, site levelling, etc. presents no hard times.

An analyses on the proposed site soil have shown that site soil is sand to sandy-loam which has the following characteristics: Soil texture and colour indicated that grains are coarse (0.02 – 2) mm in diameter grey to reddish colour; Soil

structure indicated that the soil is loose and will not cohere having more than 90% of the soil with less than 5% clay; Soil porosity and permeability indicated that the soil has wider porous spaces allowing water and air to run through it easily; therefore it is porous or highly permeable and very well drained; Workability indicated that the soil is easy to till but it is not fertile.

Normally, the type of foundation to be adopted for a building depends upon the load to be transmitted and the bearing capacity of the soil. Suitable site is selected having satisfactory subsoil (e.g. one with a good bearing capacity of reasonable depth) it is not difficult to decide upon the type of foundation here.

7. Services: - Electricity power lines run parallel to the access road at the western part of site along the road leading to senate building. This is planned to power all the proposed faculties. The power supply is tapped into the school from the distribution line leading to Gujba Local government. Other services such as water is provided from the University water supply and services unit.

5.2.2 Site shadow analysis

Shadow analysis presents that from 10 am to 12pm (2 hours) the heat is intense at the eastern parts of the site whereas from 12pm to 5pm (5 hours) intense heat is experienced at the western part of the site. The activity was carried out with a rectangular box-pattern made of paper, 1ft height and 4cm all sides. Shadow lenghts was measured at an hour sessions. The lengths of casted shadow form the form onto the surface is recorded at the sessions. Shadow analysis is graphically reported in appendix III (designed sheets).

5.2.3 Site zoning concept

The zoning of functional spaces on site was made based on two sensitive issues: heat gain and dust laden wind.

1. Heat gain; from the shadow analysis conducted on a solid object on the proposed site, shadow effect was observed to be casted for a long period at the southern face of the form. It was deduced that shadow is naturally casted at southern parts of the proposed building. It is very essential to design shades at the courtyards to be permanent casted in daytimes thereby decreasing the rate of surface heating and consequent radiation to indoor. On the floor planning, the east and west sides of the building accommodates galleries and conviniences.
2. Dust laden wind as North-East Trade Wind affected the design from the points of; Orientations that reduced direct intercept of wind by indoor users, Reduced Openings so as to control the amount of prevailing air indoor, Levels and Positioning of Openings was such that the low level openings positioned at floor level (00)mm while the high level openings positioned at the door heights (2100)mm, Thickness of Walling Materials, Wind breaker trees, etc. were all designed to control the amount of incoming air from the relevant directions.

5.2.4 Recommendations

Based on the analyses above, the cumulative effects of heat on site presents the greatest challenge as the major emphasis in the design. Site planning and design tries to solve the problems as follows:

1. The building structure is oriented N-S direction to counteract the effect of trade winds while in addition heavy landscape is planned at same direction to damp the effect of high wind flow. Thus the site is protected from the dust laden wind by emanating from N-E directions.
2. As a result of sun glare and high temperature on the site, shading devices are used on the structure to cater for uncomfortable conditions.

3. The site surface heating could be controlled by the use of grasses as ground cover in addition to the shady trees around the site as well as building structure. In this way, the ratio of soft landscape to hard landscape area is kept at 3:1.
4. The loose site sand (sandy soil) is provided with either wide strip foundations or a raft foundation to ensure that any settlement is uniform.
5. In terms of vegetation; buffer trees, shrubs and grasses should be designed to cover the bare soil on the site. Now for easy maintenance of the vegetation; Native Trees, Shrubs, and Plants not alien vegetation are selected. These have adaptive capacities to the harsh climatic conditions of the area. Plant naturally cools the air as it passes through it. The hot dry air is both hot and dusty before it passes through plantations or moist air such as fountains and ponds.
6. The stormy rainfall in rainy season necessitates the use of tall courtyard trees and overhangs in the design.
7. Services in terms of water, electricity, telecommunications, and etcetera are readily available on the site.
8. There is enough space for the development of the proposed Faculty of Environmental Sciences because it is almost a virgin land of which every portion is empty.

5.3 Design Information

Based on the information derived from the design considerations in literature review, other considerations are also incorporated from practical findings as discussed under the case studies and the field studies: the proposed building shall be a single unit of integrated functions (complex building) to be called the Faculty of Environmental Sciences for Yobe State University that is indoor thermally comfortable in the selected site within the University to serve as a model or prototype design initiation in the study area. It consist

of five (5) number of academic departments. These are Architecture Department (Arch Dept.), Building Technology Department (Bldg. Dept.), Industrial Design Department (ID Dept.), Survey and Geo-Informatics Department (LSV), and Urban and Regional Planning Department (URP Dept.).

There would be undergraduate programmes (4 years) as well as Postgraduate programmes (2 years) leading to the awards for Bachelors of Sciences (B.Sc.) as well as Master of Sciences (M.Sc.).

5.3.1 Design brief

The Faculty of Environmental Sciences houses five (5) academic departments to ameliorate the current challenges Nigeria faces in the area of Environmental studies. The departments are as follows: -

1. Department of Architecture
2. Department of Building
3. Department of Industrial Design
4. Department of Urban and Regional Planning
5. Department of Survey and Geo-informatics

The faculty complex consists of Research/ Workshop spaces, Administrative space, Design studio spaces, Teaching spaces, Circulation spaces, Offices, Postgraduate Units, etc. In terms of facilities; Educational facilities, Social amenities, Recreational facilities, etc are provided to serve both the staff and students on a total ground floor area of approximately 4,050m2 for the main block alone.

The resulting design provides an excellent working environment to encourage high quality research, teaching and learning. The building demonstrates an outstanding level of quality in relation to all of the disciplines within the Faculty. It is a building of

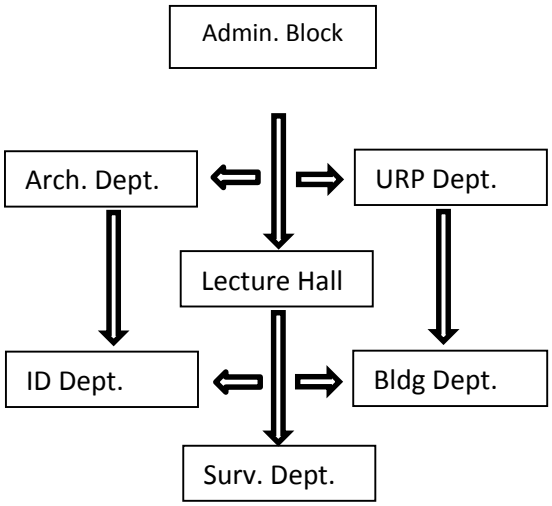
international architectural merit, with highly integrated landscaping and urban design features that will make a significant contribution to the surrounding campus and community. It demonstrates the best practices of engineering, fabrication, construction and servicing. It provides an outstanding accommodation for research activities within the faculty, comprising individual and group projects between academic staff, visiting and professorial fellows, post-graduate students, and research assistants. It also provides outstanding facilities for formal interaction between staff and students, as well as for informal and peer-to-peer learning.

Apart from the Dean's office, faculty library, ICT, conference hall and other offices in the faculty building, each department has staff offices, classrooms, studios, HOD's office, departmental library, ICT, and conference hall. The project consist of a ground floor, first floor, second floor and third floor spaces being a learning environment where there exist a diverse and complex world of people, places, and ideas. The relationship to physical spaces and technological systems to learning continues to be ever important, even more important is how, and whether, the indoor spaces for Learning support the individual perceptions on thermal comfort.

5.3.2 Space analysis

The ratio of staff to students will follow the minimum stipulated ratio as stated by the Nigerian University Commission and also found on case studies (Table 5.2, 5.3, 5.4 and 5.5). However, an additional percentage shall be added to the standard sizes in order to cater for some unforeseen circumstances like fluctuating number of students admitted or taking a particular course and even the backloads of graduating students (spill over students). Proposed space need includes the following: *Academic Space needs:* - this include the following spaces; classrooms, lecture halls, laboratories, Library/data rooms, meeting rooms/ Seminar rooms (Fig. 5.6 and 5.7). *Administrative Space needs:* - to

include Faculty offices, Extra offices for staff and students (Fig. 5.8). *Ancillary Facilities:* - Parking spaces, Business centres, Sit outs and gardens (Fig. 5.9).



Flow chart of functions on Site
Source**:** Researcher's Design, 2014

Table 5.2: Basis on the Number of Students in each undergraduate class.

Case/Bldg	Arch. Dept	Bldg Dept	I.D. Dept	URP Dept	E.M.T. Dept	Survey and Geo Informatics Dept	Geogr Dept
Casestudy2	40	30	20	30	-	40	40
Casestudy1	40	30	-	30	30	40	-
Proposal	60	40	30	40	-	30	-

Source**:** Researcher Field work, 2014

From table 5.2, the number of students in each department was derived from case studies. In terms of facilities, reference shall always be made for the maximum number prescribed above.

Table 5.3: Basis on the Number of staff and office needs.

Case/Bldg	Arch. Dept	Bldg Dept	I.D. Dept	URP Dept	E.M.T. Dept	Survey and Geo/QS Informatics Dept	Geogr Dept
Yola	16	8	15	14	-	13	16
Bauchi	24	14	-	15	14	15	-
Proposal	30	20	15	20	-	15	-

Source**:** Researcher Field work, 2014

From table 5.3, the number of staff/offices in each department was derived from case studies. In terms of facilities, reference shall always be made for the maximum number prescribed above.

Table 5.4: Number of students expected in each class for each department.

S/NO	Department	100 level	200 level	300 level	400 level	M.Sc I	M.Sc II	TOTAL
1.	Architecture	60-80	60-80	60-80	60-80	80-100	80-100	400- 520
2.	Building	40-60	40-60	40-60	40-60	60-80	60-80	280- 400
3.	Industrial Design	30-40	30-40	30-40	30-40	40-60	40-60	200- 280
4.	Urban and Regional Planning	40-60	40-60	40-60	40-60	60-80	60-80	280- 400
5.	Survey and Geo-informatics	30-40	30-40	30-40	30-40	40-60	40-60	200- 280
TOTAL	Five (5)	200-280	200-280	200-280	200-280	280-380	280-380	1360-1880

Source**:** Researcher Field work, 2014

From table 5.4, the population of students in the faculty building is projected to be between 1360 to 1880 students. In terms of the faculty facilities, reference shall always be made for the peak populations.

Table 5.5: Number of Academic Staff according to departments.

S/NO	Department	NUC Ratio	Student Population	Staff Population
1.	Architecture	1:15	400- 520	27-35
2.	Building	1:15	280- 400	19-27
3.	Industrial Design	1:15	200- 280	14-20
4.	Urban and Regional Planning	1:15	280- 400	19-27
5.	Survey and Geo-informatics	1:15	200- 280	14-20
	TOTAL		1360-1880	93-129

Source**:** Researcher Field work, 2014

From table 5.5, the number of staff/offices in each department was derived from provisions by the NUC. This was however used in addition to the information found on case studies. In terms of facilities, reference shall always be made for the maximum number prescribed above.

Table 5.6: Schedule of spaces for the five (5) departments

S/No	Space Name	Dimension (mm)	Quantity	Square Meter $(m)^2$
1.	Classrooms/Studios	9000 x 18000	30	4860
2.	Seminar Halls	12000 x 18000	5	1080
3.	Offices	4000 x 4000	30	480
4.	Library	12000 x 18000	5	1080
5.	ICT Networking Room	4500 x 6000	5	135
6.	Archives/Data Room	12000 x 18000	5	1080
7.	HOD's Office	12000 x 18000	5	1080
8.	Utility/Store	3000 x 6000	5	90
9.	Conveniences	6000 x 6000	5	180
10.	Circulation Space	4000 x 12000	5	240
11.	Exams Officer	6000 x 12000	5	360
12.	Workshops/Laboratories	12000 x 22000	5	1320
Total				**11985**

Source**:** Researcher's Design, 2014

From Table 5.6 above, the proposed space need for the five departments covers an area of 11985m² as scheduled but this proposal alone will cover an area of about 25% of the site size which is 47543m². It is therefore imperative to superimpose some blocks into storey buildings for additional space.

Table 5.7: Schedule of spaces for the lecture halls

S/No	Space Name	Dimension (mm)	Quantity	Square Meter (m)²
1.	Book/Printing Shops	4500 x 4500	4	81
2.	Stage	4500 x 12000	4	216
3.	Seating Space	1200 x 22000	4	1056
4.	Circulation Space	4500 x 22000	2	198
Total				**1551**

Source**:** Researcher's Design, 2014

From Table 5.7 above, the proposed space need for lecture hall buildings will cover an area of 1551m² as scheduled above. This is about 3% of site size.

Table 5.8: Schedule of spaces for the faculty Administrative Block.

S/No	Space Name	Dimension (mm)	Quantity	Square Meter (m)²
1.	Dean's Office	9000 x 18000	30	4860
2.	Faculty Library	12000 x 18000	5	1080
3.	Faculty Exhibition Hall	4000 x 4000	30	480
4.	Faculty Offices	12000 x 18000	5	1080
5.	Conference Hall	4500 x 6000	5	135
6.	ICT Control Room	12000 x 18000	5	1080
7.	Data Room	12000 x 18000	5	1080
8.	Maintenance Office	3000 x 6000	5	90
9.	Faculty Store	6000 x 6000	5	180
10.	Conveniences	4000 x 12000	5	240
11.	Circulation Space	6000 x 12000	5	360
12.	Gallery/Reception	12000 x 22000	5	1320
13.	External Defence Room			
14.	PG Coordinator			
Total				**11985**

Source**:** Researcher's Design, 2014

From Table 5.8 above, the proposed space need for the faculty buildings will cover an area of 1626m² as scheduled above.

Therefore, the total of 11985m² + 1551m² + 1626m² = 15162m²

Now, if the total site area is given as 47543m² with reference to the above summation (15162m²), the proposed project site coverage would be about 32% at the onset of the design. To save more space and allow for parking space and green area on site, the design will be superimposed into the three storey building of First floor, Second floor, Third floor in addition to the Ground floor so that the proposed project site coverage would be of about 12% (Fig. 5.9) at the onset of the design.

Table 5.9: Summary of Schedules for the proposed faculty buildings.

S/No	Space Name	Percentage Coverage	Site Area Covered
1.	Proposed Faculty Building	12%	5,705.16 m²
2.	Parking Space	20%	9,508.6 m²
3.	Green Area	40%	19,017.2 m²
4.	Future Expansion Space	28%	13,312.04 m²

Source**:** Researcher's Design, 2014

5.3.3 Conceptualised design information

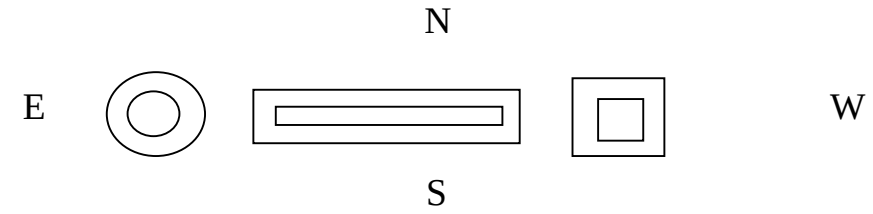
5.3.3.1 *The design forms*

The forms were chosen and designed based on the principles of bioclimatic response in the following phases (phase one and two):

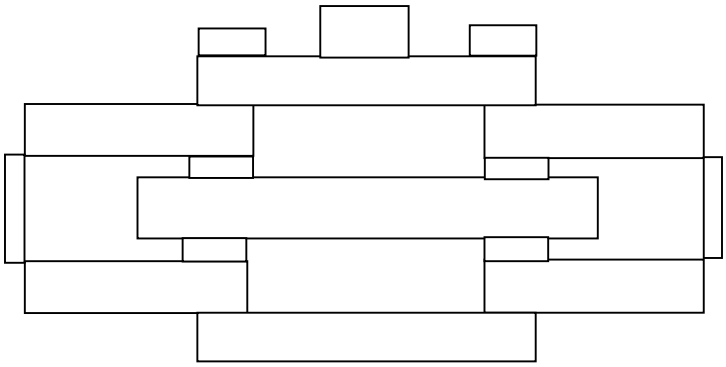
Phase one (plan form): -

1. Rectangular form was adopted from the previous studies because of its longer sides facing north/south directions and its reduced surface area exposed to weather as compared to other shapes when two forms formed a complex. The effect of outdoor heating to the indoor spaces is further reduced when this form is oriented as shown below. Shading devices around the form could also provide an additional cut at the solar heating effect. Impluvium/courtyard as a form of courtyard could

help drive the unwanted hot dry outdoor air off the functional indoor spaces. Circular and Square forms could not give this.



2. Composite rectangular forms are combined in the course of this design according to researcher's planning. The forms are combined in a staggered manners so that the prevailing high wind speed observed from the field survey is decreased. Multiple courtyards are designed such that the hot air is humidified within it prior to entering into the functional spaces.

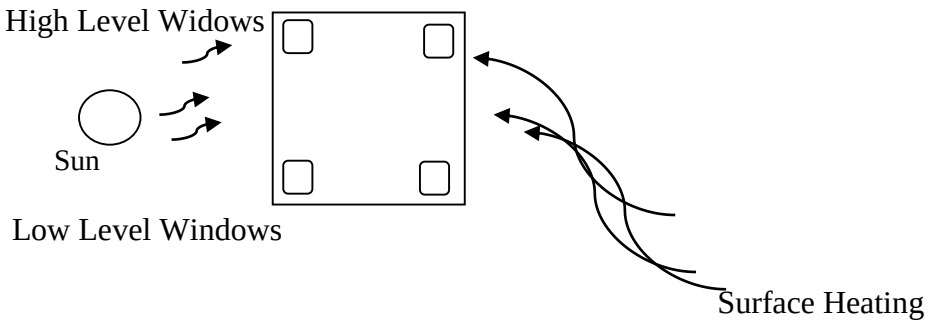


Phase two (elevation form): -

3. The principles of solar incident radiation is adopted as an idea behind the design guides for the elevation. It therefore led to the following designs: -

   i. Smaller sized high level and low level openings: the larger the openings the greater the exposure of indoor spaces to outdoor hot dry air; The lower opening at 300mm above floor level while the higher opening at 300mm above lintel level. Each of the small-sized opening is 900mm in heights.

   ii. Deciduous trees at the faces of elevations: the greater the portion of the building to standout in height above other part, the greater its exposure to radiant solar heating.



5.3.3.2 The site.

Filtration of dust and breaking the wind storm on site:

The high speed of the prevailing north east trade wind which is the major driven force for the heated and dusty air into the area was controlled through the use of buffer trees at the NE directions (Fig 5.6). Native deciduous trees were selected to keep the wind direction offsite as it travels along the differences in the heights of these trees.

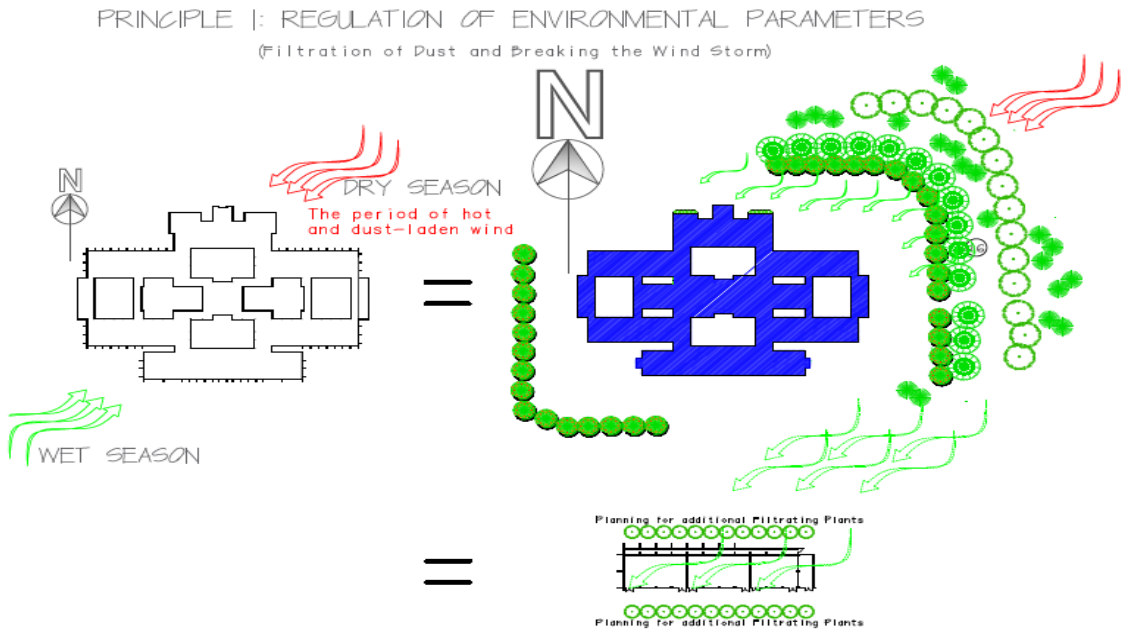


Figure 5.12: Proposed Wind Buffer Trees at relevant Directions on site.
Source**:** Researcher's Design, 2014

Green area on the site landform:

The proposed site was relatively flat and so it gets heated uniformly during the day, grasses was used as ground cover or landscape element to undermine the site surface heating. About 40% of the site was reserved for this purpose (Fig 5.7).

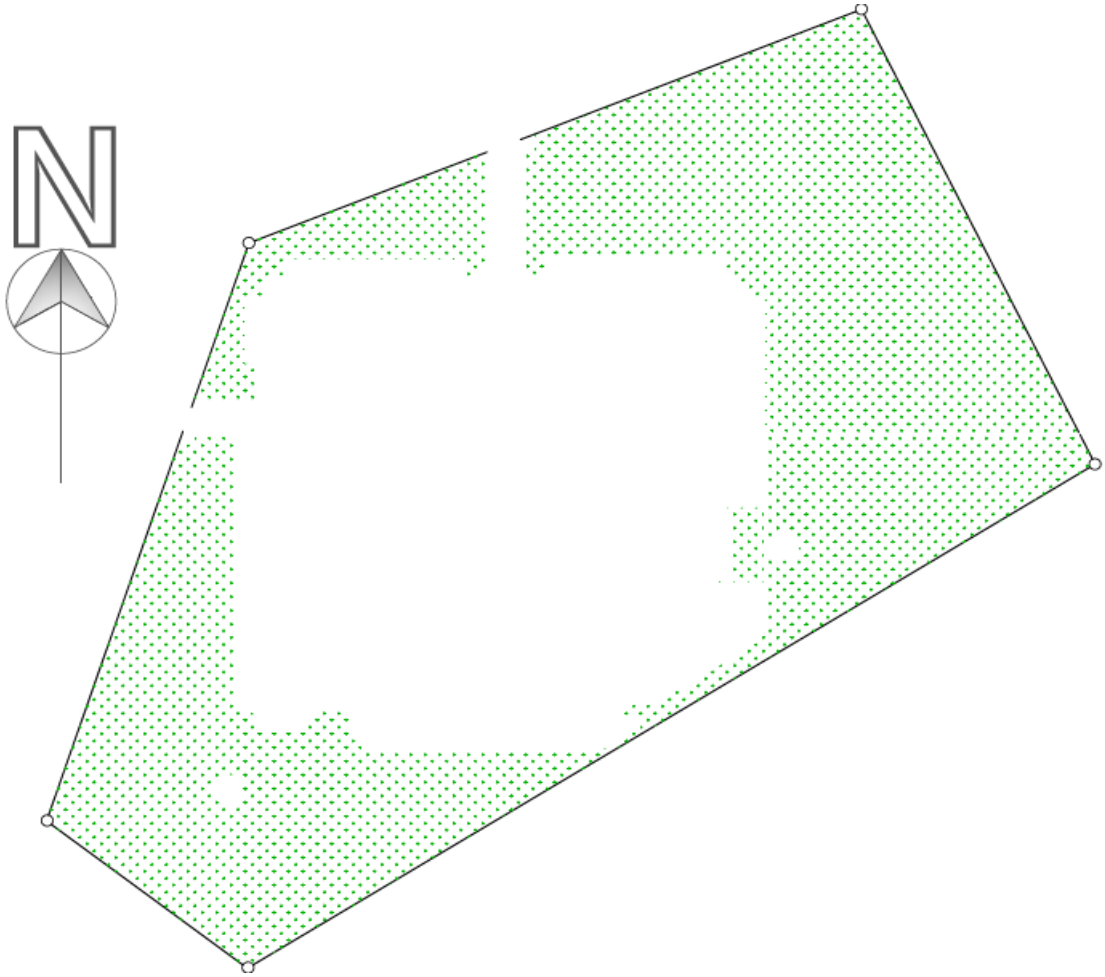


Figure 5.13: Proposed Ground Cover Landscape Grasses (40% of site size).
Source**:** Researcher's Design, 2014

5.2.7.3 Building on the site.

Humidification of dry air in and around the building:

Fountains were designed within and outside courtyards on the site to help humidify the air and make it thermally comfortable within the indoor spaces. For evaporative cooling, Roof Garden and Balcony Garden were designed at higher level to filtrate as well as cool the incoming air to the indoor spaces. Drought resistant plants were selected to help sustain the maintenance expenditure. It was also desirable to cast shadow around the building so that the surface heating is reduced. (Fig. 5.8 and 5.9) presented the evaporative cooling.

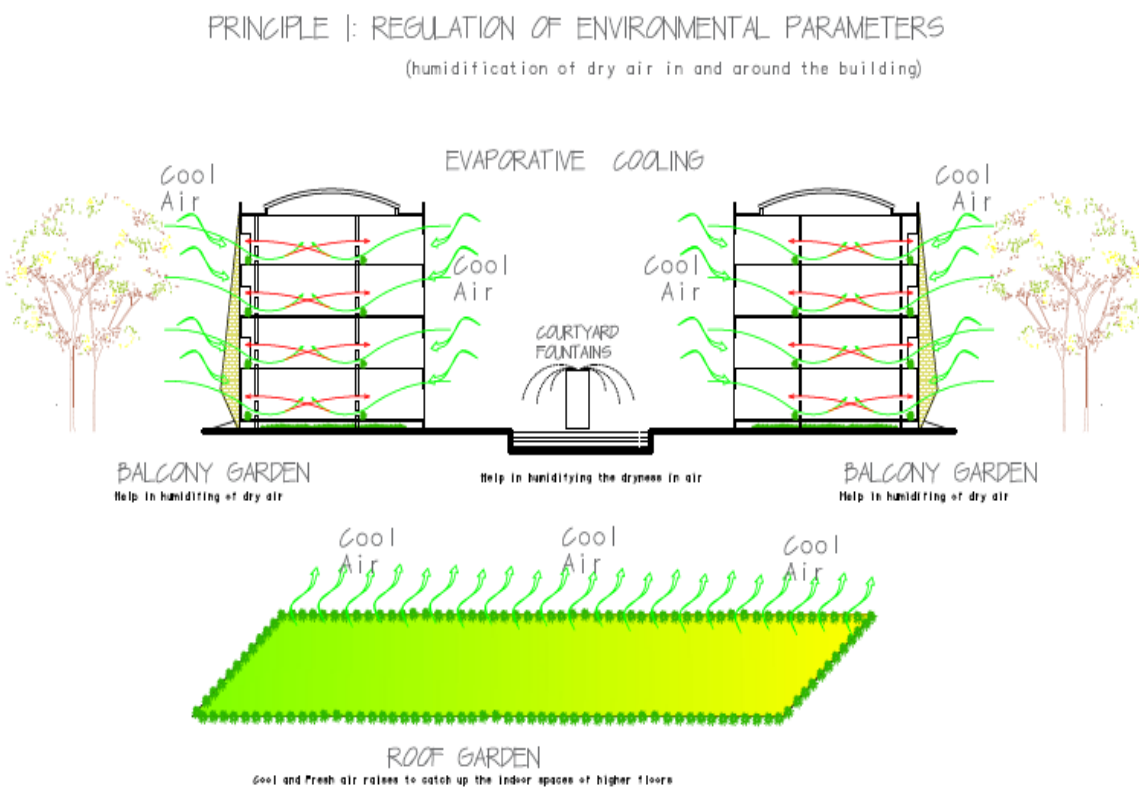


Figure 5.14: Evaporative Cooling from plants
Source**:** Researcher's Design, 2014

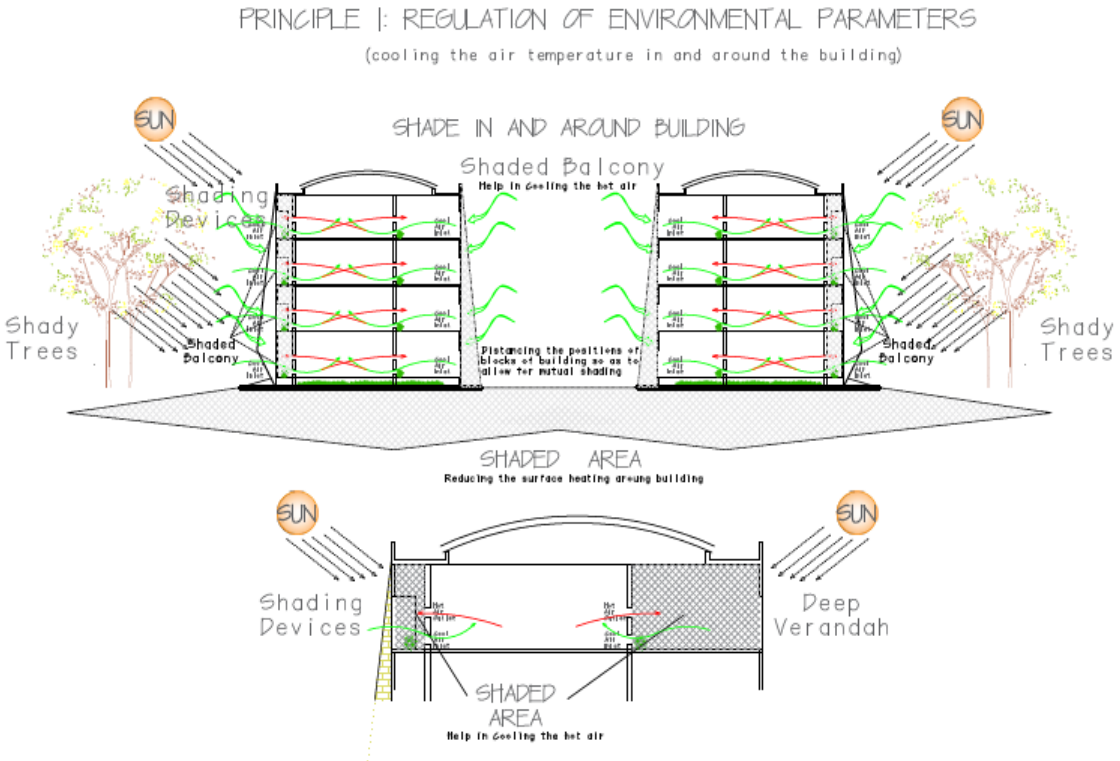


Figure 5.15: Natural cooling through shadow casting
Source**:** Researcher's Design, 2014

5.2.7.3 The building envelope

Sealing the walls:

In a typical hot-dry climate where there is a large diurnal temperature variation, (between too hot and too cold), massive construction of external/enveloping walls may provide the full solution in regulating indoor conditions to the comfort of indoor users (K. Thomas, 1995). In this design, the thermal mass of enveloping walls is increased from the U value of 0.60 to that of 0.50, and when compared to the normal 150mm or 230mm thick block walls used in designing case study buildings in the area, it could be rightly to say the indoor condition would now get thermally stable since heat flow through three materials of wall got reduced by the thermal resistance of such materials. The construction of the cavity wall is as follows: 100mm thick brick wall as internal leave, 50mm air space cavity wall, 150mm block wall as external leave and 15mm lightweight plaster on one or both sides. It could be seen in Fig 5.10 below. The method of calculating U value is presented on Table 5.9 below.

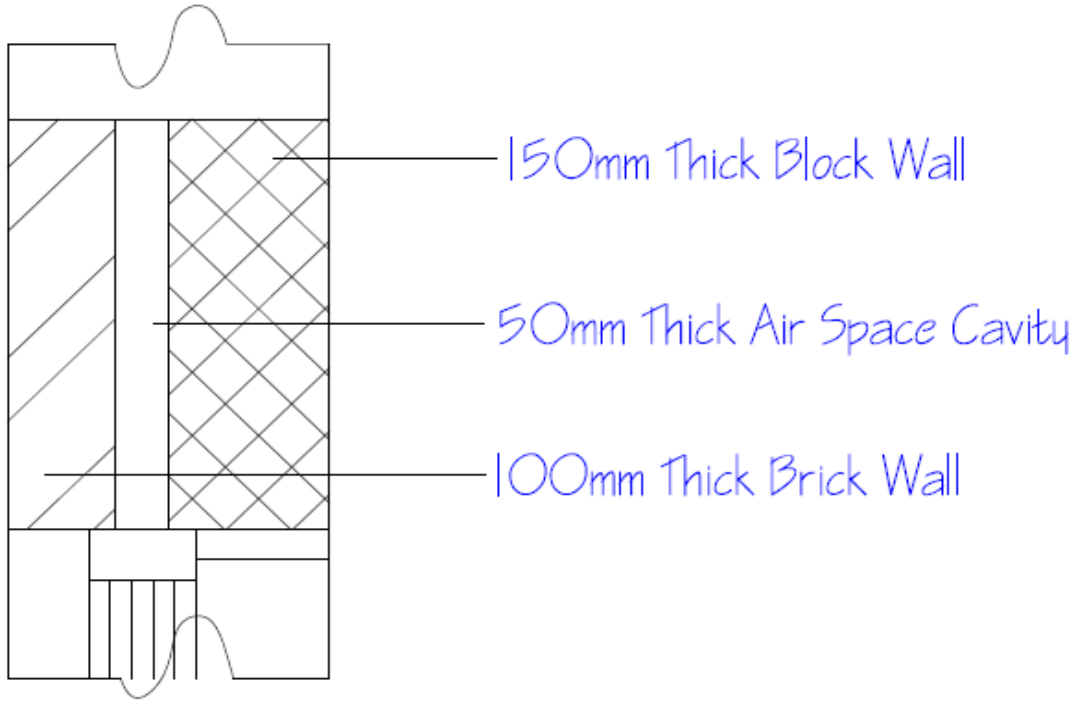


Figure 5.16: Composite cavity walls around the building envelope
Source**:** Researcher's Design, 2014

Table 5.10: Thermal resistance as heat flows through the three material layers.

Material	Thickness (m)	Thermal Conductivity (W/mK)	Thermal Resistance (m²K/W)
External Wall Surface	-	-	0.06
Standard Brick	0.102	0.84	0.12
Air Space	0.50	-	0.18
Light Weight Block	0.150	0.132	1.32
Light Weight Plaster	0.015	0.185	0.18
Internal Wall Surface	-	-	0.12
		Total Thermal Resistance	= 1.98

U value = 1/Thermal Resistances

= 1/1.98

= 0.5W/m²K

U value or thermal transmittance coefficient is defined as the rate of heat transfer in watts through 1m² of a wall when the temperature on each side of the wall differs by 1ºC.

Thermal conductivity = Heat flow rate ÷ (Area × Temperature gradient). In the SI system of units, thermal conductivity is measured in **watts per metre-kelvin**,

(W·m-1·K-1) where: watt is the unit of power and metre is the unit of distance

Openings/fenestrations on walls:

The concept behind this was the reduction of heat gains into the building which was ensured by the reduced sizes and number of openings around the building so that a greater portion of the building is walled up. Fig. 5.11 below showed the positioning and the sizing of openings used in studios, lecture halls, laboratories, etc.

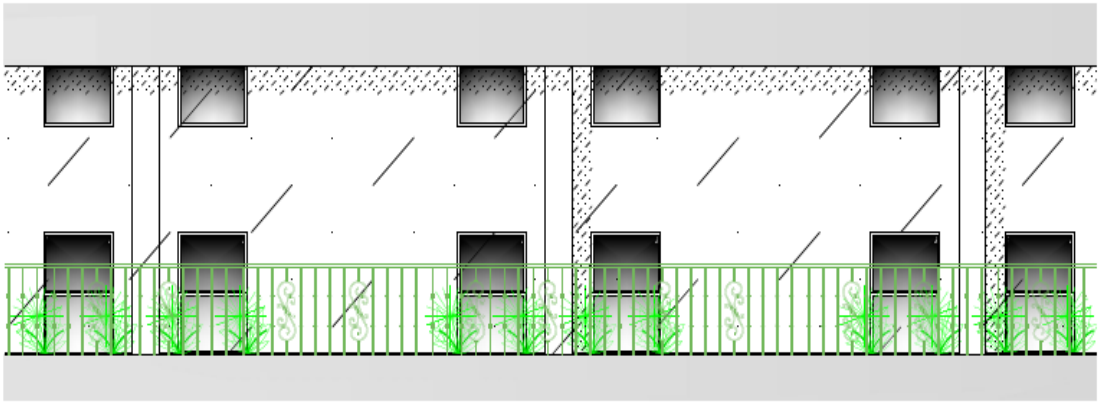


Figure 5.17: Sizing, Positioning and Numbering of openings.
Source**:** Researcher's Design, 2014

Another control measure to wall up a greater portion of the envelope was the use of wall blinds at the administration block since there is no need to plant too many trees at the approach view of a public building. The use of glaze was also minimised. Fig. 5.12 below presented how the wall blinds were incorporated in design.

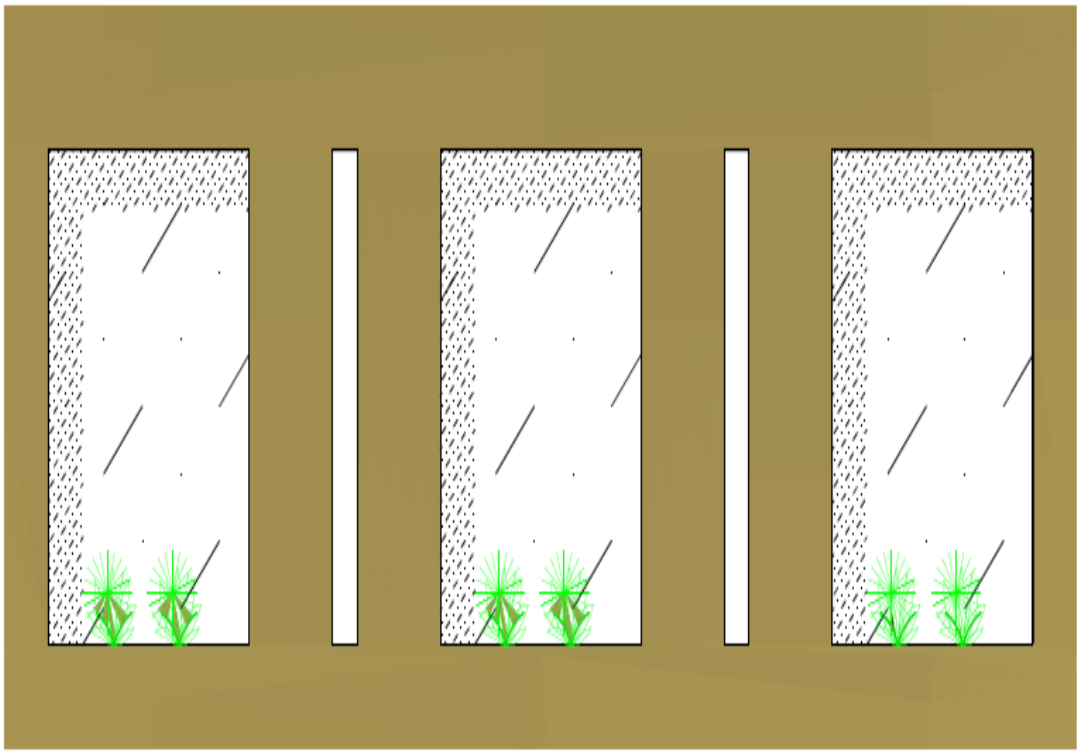


Figure 5.18: Use of wall blinds for shading effect in the façade.
Source**:** Researcher's Design, 2014

5.2.7.4 Street width and Orientations.

Roadways and built-up structures within site were all designed with shady trees by the sides. Distances between blocks of buildings on site was kept minimum to allow for a mutual shade as in Fig. 5.13. South and north facing walls were easier to shade than east and west walls, therefore greater number of openings were provided at south and north facing walls.

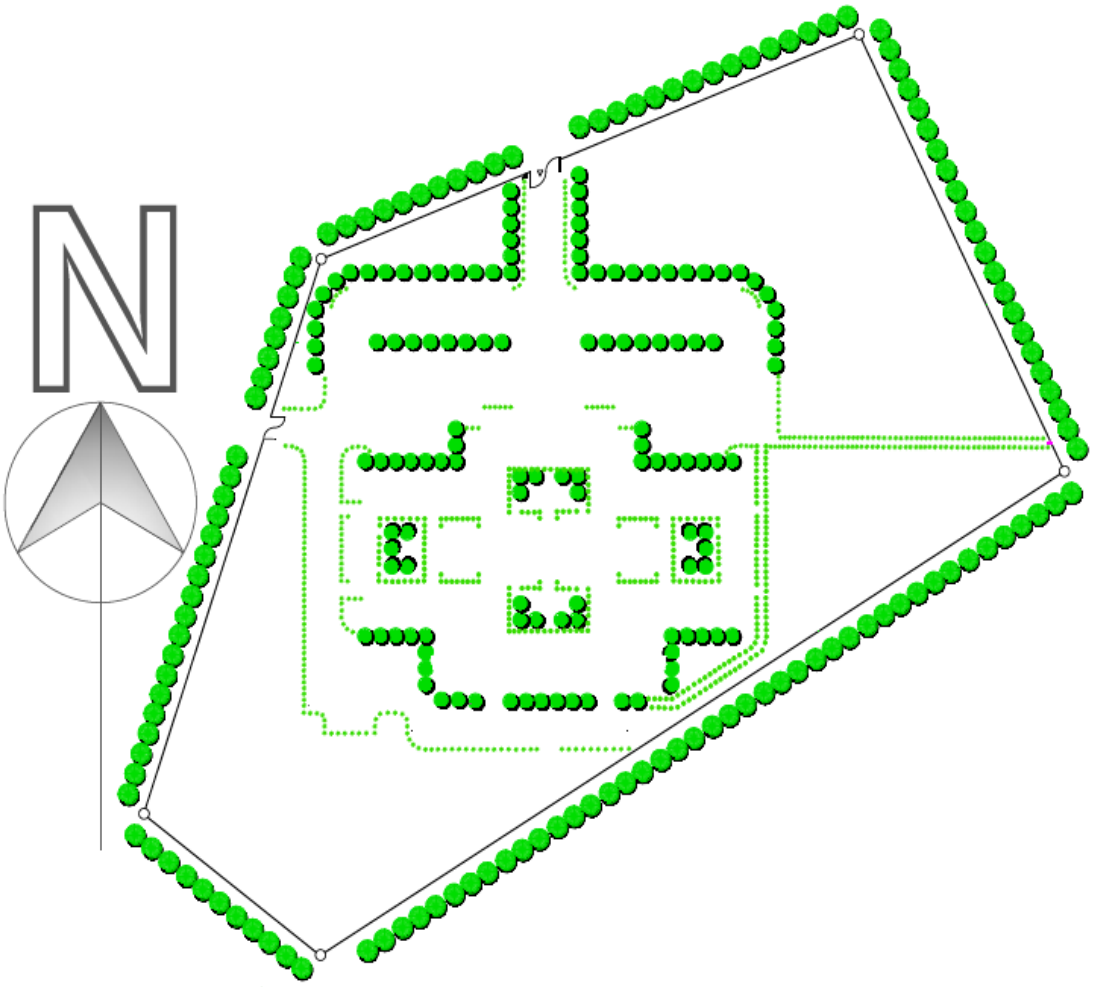


Figure 5.19: shady trees in and around built up forms
Source**:** Researcher's Design, 2014

5.2.7.5 Open space and built-up areas

The ratio of built-up and open space on site is designed to be 3:7 from the space schedule for the proposed project as in Fig. 5.14. The ratio gave enough room for any future expansion. It also took care of need to minimise hard surfaces on site which were believed to raise the temperature of ambient air.

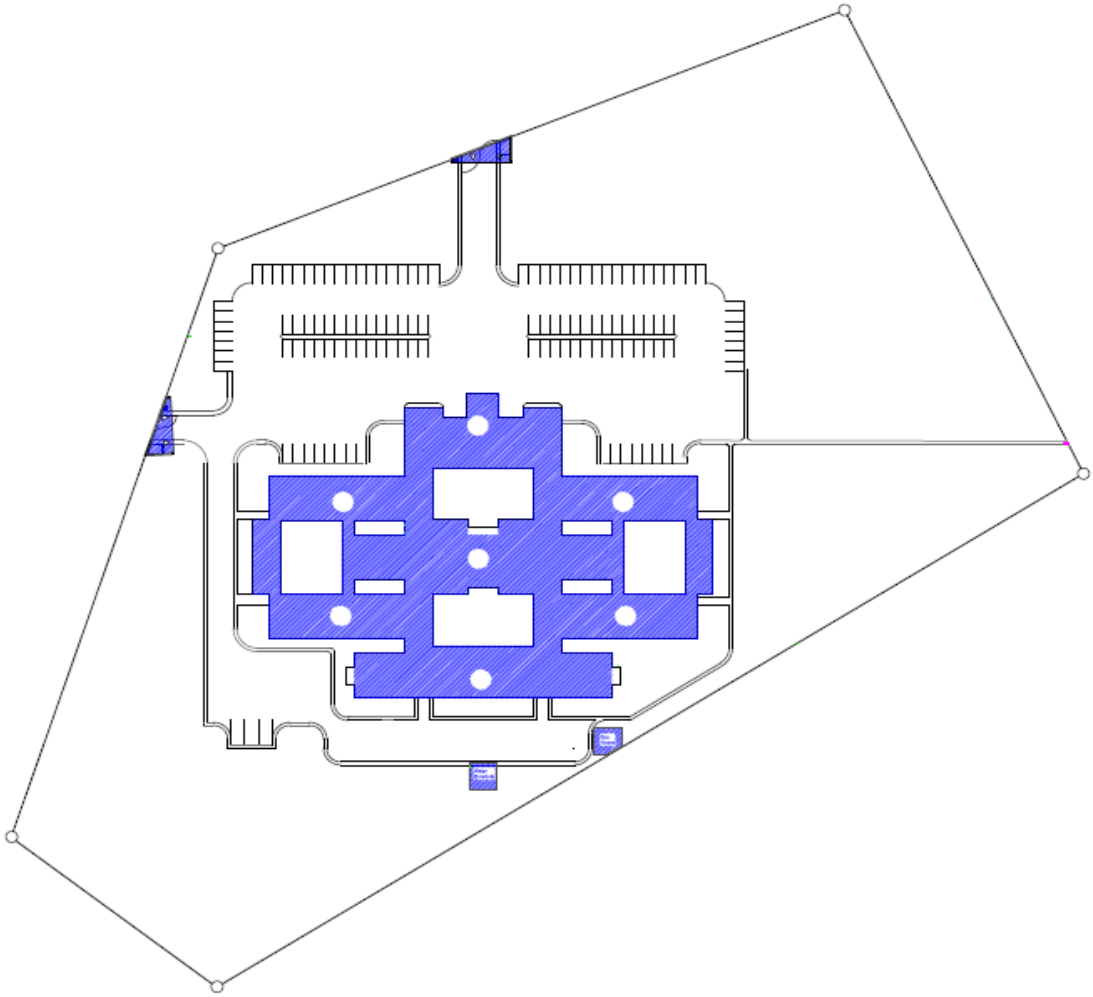


Figure 5.20: Ratio of built-up space and open space on site.
Source**:** Researcher's Design, 2014

5.2.7.6 Orientation and Plan form

The eastern and western walls are significantly exposed to solar radiation in the area, this leads to a very high temperatures for indoor spaces adjacent to those sides as in Fig. 5.15. Despite adequate tree shading, functional spaces to be used in the day time were all designed along the southern and northern sides of the building form thereby elongating the N-S orientations over the western and eastern aspects. The plan form has always follow the footprint or features of bioclimatic building for the area.

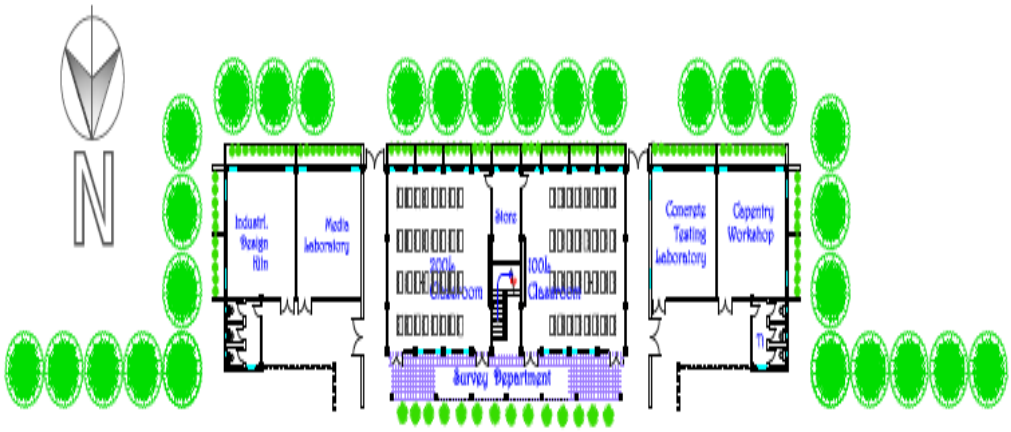


Figure 5.21: Longer N-S orientation over the W-E aspects on site.
Source**:** Researcher's Design, 2014

5.2.7.7 The Roof

The vaulted roof reduce heat gains from the bioclimatic analysis as shown in Fig. 5.16.

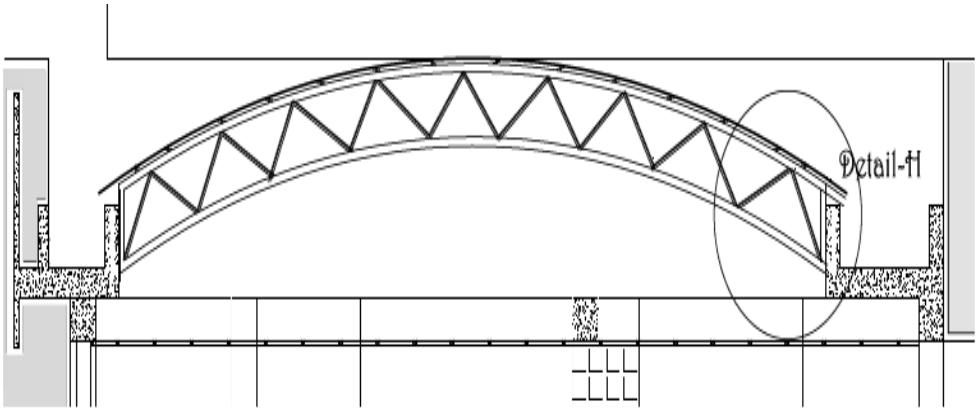


Figure 5.22: Use of vaulted roof to reduce heat gain on building form.
Source**:** Researcher's Design, 2014

5.2.7.8 Colour and Texture

Due to the dusty nature of the area, very brighter colour could not be used. Therefore, light-brown colours and Ash colours were variously employed as wall paints as in Fig. 5.17.



Figure 5.23: Colours to match the dusty nature of the area.
Source**:** Researcher's Design, 2014

5.4 Building Services

Environmental standards were observed within designed spaces to improve the health of indoor users as follows:

1. Lighting: In this design, natural means of lighting was employed at the galleries, verandas and corridors as well as the classrooms through the wider windows facing the courtyards and high/low level windows facing the outside environments. Artificial lighting system is sourced from solar panels over roofs to reduce cost of artificial light electrification.

2. Ventilation: - Mechanical assistance is proposed in extreme cases where full air-conditioning will be necessary or where the classroom cannot have the height to induce air flow by natural stack effect (lecture hall within courtyards). It is normally more economical and energy efficient to have separate air-handling units for each block on site, managed by time switches and occupy sensors.

3. Fire Safety: - as fire protection, a wider staircases of width of 2.4m, 3.0m and 4.0m was used to allow the number of people in the storeys under a state of emergency of fire outbreak to escape the building safely. This width was chosen to reflect the total exits serving it. The staircases started at the lower level and then bifurcated at the middle leading to the wings of the building. Also the use of structural frame of concrete material at the central portion of all stairs is to aid fire protection. Smoke detectors also used at various points in the building. The use of void at the stair wells from upper floors down at administration block presents an added effort to fire and smoke control within the gallery.

4. Power Supply: - as a means of alternative energy source, solar panels and a standby generator, were used in the building as an alternative to the NEPA supply which is unreliable. The generator is to be positioned at the rear noisy area near workshops on the site. The solar power and the generator take care of the sudden or eventual power failures, especially when an important congregation or lecture session is on progress.

5. Clean Water supply: - bored hole is drilled at rear position on site near the generator position. This water is piped and stored in overhead tank which would be positioned on top of roofs for easy pumping potentials down the structure.

6. Storm Water Drainage: - storm water drainage either collected down the roof gutters, site surfaces and used off in conveniences were taken care of through the use of various drainage basins in the form of surface and underground gutters. The lawn and other flowers are irrigated in this way.

6.0 CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The study has identified that the principles of bioclimatic design are appropriate to be applied in design to solve the buildings' problem of indoor thermal discomfort by designers in the hot dry area.

According to this research, the measure of indoor air temperature and indoor air relative humidity within buildings that have applied 40% of appropriate and adequate bioclimatic responses in the area revealed the following results: 47% of indoor users were uncomfortable with the 31ºC indoor air temperature; 43% of indoor users were uncomfortable with the 33RH% indoor air relative humidity but almost all the respondents were comfortable with the indoor air speed.

That gave the researcher a focus on the two variables that were perceived uncomfortably by indoor users even though the respondents' were to some extent also tolerant with the indoor thermal discomfort nature of the study area (adaptation). Thermal conditions for building users in the area had already been shifted up above normal values (see research assumptions on chapter three).

Generally speaking, it is now hoped that the proposed design concepts postulated and tested above in design of faculty of Environmental Sciences for Yobe State University acts as a prototype design guide on achieving a bioclimatic responsive buildings in hot dry areas.

6.2 Recommendations

To further contribute on this study, the following recommendations would have to be considered about the use of bioclimatic response for indoor thermal comfort in hot dry climate:

1. Designers must bear in mind that the effect of bioclimatic response on building's indoor conditions lies in the high rate/percentage of adequately applied principles in its design. The relationship is such that the percentage of adequately applied (AAP)% principles are directly proportional to the indoor thermal comfort conditions for the indoor users in the study area. The researcher now estimates, with reference to the findings, that the (AAP) % must reach at least ≥50% before the indoor conditions of buildings become theoretically comfortable enough the required 80% of the indoor space users.
2. Designers must also bear in mind that all the appropriate principles of bioclimatic design especially for the area are incumbent to be adequately applied in design for an ideal indoor thermal comfort in hot dry area as indicated above.
3. Designers must devise other means to control the transfer of heating into the indoor spaces in the area. Not necessarily the use of cavity construction but also other options like the use of massive walling material, increasing the thickness of block walling, etc. all to ensure that the enveloping walls take longer time to conduct heat from the outside environment.
4. Designers must devise ways of integrating the principles of bioclimatic design for the climate while ensuring that it does not constrain them of their taste to express complex thoughts accordingly.

6.3 Contributions to Knowledge

1. The study has justified that bioclimatic design principles as designers' tool could be subjectively and objectively set to minimise the problems high energy consumption and thermal discomfort in hot dry climate.
2. The study has established a relationship between bioclimatic design principles and indoor thermal comfort conditions in buildings in hot dry area. It is such that the percentage of adequately applied principles (AAP) % are directly proportional to the percentage of comfort votes by the indoor users. This indicates that the more bioclimatic principles are applied, the more comfortable building users will be.
3. The study has also highlighted the selection of native plants as the sustainable means of maintaining a bioclimatic design concepts in drought conditions.
4. The study has reintroduced the use of multiple instruments of data collection objectively and subjectively in comparative studies like this.
5. The study has proposed design concept for a model building in the study area.
6. Lastly the study revealed that shadow analysis could be an important design tool for thermal comfort studies in a local environment, especially a hot dry condition, like the study area.

LIST OF REFERENCES

Academia (2014) Design with Climate – Hot and Dry climate Design. Reyrieved online, uploaded by Hossein Medi via http://www.academia.edu/1738181/ Design_with_Climate-_Hot_and Dry_Climate_Design

Alamu J. F. and Olukosi (2010) Simplified Research Methodology – Principle and Practice, Great Glory Publishers, Zaria. Samaru

ANSI/ASHRAE Standard 55 – 2010, Thermal Environmental Conditions for Human Occupancy, ANSI-ASHRAE Standard 55-2010, retrieved via http://www.ashrae.org/template/TechnologyLinkLand/category/163

Barry, R. (1999). The Construction of Buildings (7th Edition ed., Vol. IV). London: Blackwell Science Ltd.

BioclimaticX (2013) what is Bioclimatic Architecture? an article retrieved via http://bioclimaticx.com/bioclimatic-architecture1/ <op.mhtml.1363270119663.ac08d326172c95da@10.255.0.83>

Brian Edwards (2011) Distinctions of green, eco, bio-climatic and sustainable design, sustainability hub, Retrieved from http://www.architecture.com/SustainabilityHub/Designstrategies/ Introduction/1-0-2- <op.mhtml.1363268806444.6260db4f150795a9@10.255.0.83>

BS EN ISO 7730 Ergonomics of the thermal environment. Analytical determination and interpretation of thermal comfort using calculation of PMV and PPD indices and local thermal comfort criteria

Chenvidyakarn T., (2007) Passive Design Techniques for Thermal Comfort in Hot Humid Climate, pdf, 2007, www.shibaura-it.ac, Accessed: September 9, 2011.

Commonwealth of Australia, Bereau of Meteorology (ABN 92 637 533 532), Bioclimatic: 'Climate and Architecture' Torben Dahl, Routledge, 2009 retrieved from http://www.bom.gov.au/climate/environ/housedesign/HSMW_d.shtml <op.mhtml.1363262801186.93707e5a3c2af3e2@10.255.0.83>

Community Portal of Nigeria (2012) Nigeria: PHYSICAL SETTING – Yobe State posted to the web: 2/12/2003 8:38:46 AM retrieved from http://www.onlinenigeria.com/links/yobestateadv.asp?blurb=382

Concept Bio (2008) Bioclimatic Architecture and Buildings, retrieved from mobile search via http://www.concept-bio.eu/bioclimatic-architecture-buildings.php <op.mhtml.1363270206578.dc057a0f4f6ccc9d@10.255.0.83>

DailyPost Nigeria Online Newspaper (2012) The Story of Yobe State University's Meteoric Growth- an article 4 posted by Alhaji Yusuf Alhaji retrieved from http://dailypost.com.ng/2012/11/14/alhaji-yusuf-alhaji-the-story -of-yobe-state-university's/meteoric-growth/

D. A. McIntyre, 'Indoor Climate', Applied Science Publishers, Barking London, 1982.

de Dear, R & Brager, G. S. (1998) Developing an Adaptive Model of Thermal Comfort and Preferences, ASHRAE Transaction.

Energy Design Partnership,E.D.P. energy solutions (2013) Principles of Bioclimatic Design retrieved from http://www.edpenergy.com/index.php?_ 71:2011-04-06-11-36-28&Itemid=&lang=en

Fislisbach and Zollikon (1993) Climate Responsive Building – Appropriate Building Construction in Tropical and Subtropical Regions.

Gire M. M. (2010) proposed school of environmental science, FUT Yola. Unpublished M.Sc Thesis, Ahmadu Bello University, Zaria. Nigeria Retrieved from http://www.greenhomebuilding.com/sustainable-architecture.html.

Green G. (2013) Human Comfort Zone, pdf retrieved from http://www.greengaragedetroit.com/index.php?title=Human_Comfort_Zone#Strategy_and_Conceptual_Design

Haddad S., King S. and Osmond P. (2014) Enhancing thermal comfort in school Buildings. 10th International Healhy Buildings Conference, at Bristane, Volume: Proceedings, Healhty Buildings 2012

Hussein I., 2009 Field Study on Thermal Comfort in Malaysia *Journal of Scientific Research*: ISSN 1450-216X Vol.37 No.1 (2009), pp.127-145 via http://www.eurojournals.com/ejsr.htm

Idris A. F. (2012) Application of Bioclimatic Design Principles in the Design of Jabi Lakeside resort, Master of Science Thesis, Ahmadu Bello University,(2012) Retrieved from http://www.greenhomebuilding.com/sustainable-architecture.html.

Impact of Indoor Air Temperature and Humidity in an Office on Perceived Air Quality, SBS s symptoms and Performance published by the *Indoor Air, International Centre for Indoor Environment and Energy,* Technical University of Denmark, 2004.

Kumar K. (2010) Handbook on Energy Conscious Buildings. Pilot Edition: May 2006 Retrieved via www.scribd.com/doc/40460303/handbook-on-energy-conscious-buildings

Marincic, I. et-al, (2009) Adaptive Thermal Comfort in Warm Dry Climate: Economical Dwellings in Mexico the 26th Conference on Passive and Low Energy Architecture, Quebec City, Canada, 22-24 June 2009. Downloaded via http://www.plea2009.arc.ulaval.ca/Papers/2.STRATEGIES/2.3%20Post-Occupacy%20evaluation/ORAL/2-3-12-PLEA2009Quebec.pdf

The Ministry of New and Renewable Energy, MNRE and IRED (2010) Hot and Dry

Climate, Green Buildings - The Ministry of New And Renewable Energy - Explore: retrieved via http://ncict.net/Explore/HotDry.aspx <op.mhtml.1363262658513.ed0d736a13328ab0@10.255.0.83>

Mustafa F. (2011) Designing an Eco-friendly Resort in hot and dry Climate, Dutse. Unpublished M. Sc. Thesis, Ahmadu Bello University, Zaria, Nigeria

Nicol and Humphreys, (1996) Adaptive Thermal Comfort and Sustainable Thermal Standards for Buildings

Nicol, (2004) 'Adaptive Thermal Comfort Standards in the Hot Humid Tropics', Energy Buildings, 2004

Occupational Safety and Health Service (1997) *Temperature in Places of Work*, Department, of Labour, Wellington, New Zealand

Olesen W. B., (2000) Guidelines for Comfort. ASHRAE Journal of August 2000,

Turfgrass Producers International TPI, (2014) Grass Varieties Retrieved via http://www.turfgrass.org/pages/consumer-sources/types-of-grasses.

Ramblingsdc.net (2011) Passive Temperature Control in Buildings retrieved via http://ramblingsdc.net/PasTempControl.html

Soomro, A. R. (2012) Eco.Town Planning Guidelines for Hot and Dry Climate Regions From Architectural Perspective, *Review and Planning Workshop on Eco Town*, Kuala Lumpur

Thomas K. (1996) Masonry Walls, Specification and Design published by the British Library Cataloguing with the ISBN 0 7506 2465 5, printed by Hartnolls Limited, Bodmin, Cornwall

Uzuegbunam F. O. (2011) Design of a Faculty Building: A Case Study of Faculty of Environmental Studies, University of Nigeria, Enugu Campus.

List of Appendices

Appendix I: (Visual Survey Checklist)

(**Introduction**)

Thesis Title*: - Bioclimatic Response in Design of Faculty of Environmental Sciences in the Hot-Dry Climate of Yobe State University, (YSU) Damaturu*

Name of University…….....

Name of Case study (Faculty).....

Date.....

PRINCIPLES		*RATING SCALES FOR BIOCLIMATIC RESPONSES ON THE CASE STUDIES AS (AAP%, IAP% and NAP%)*			*BIOCLIMATIC DESIGNS AS CODES*
		CASE STUDY 1	*CASE STUDY 2*	*CASE STUDY 3*	
Site Landform	*- Undulating site must position plan on leeward side of the slope.* *-Site in depression is preferable in cases where ventilation is assured.* *-Flat site must landscape the surface with grasses as ground cover and as wind buffers.*				P1
Water bodies	*Water bodies (ponds, lakes, fountain, and water cascades) must be used in the vicinity of building to act as heat sink to humidify the air and make it comfortable inside.*				P2
	Distances between buildings must be narrow so that they mutually shade one another.				P3

Street width and Orientation		*Streets facades must be oriented or protected by landscape against the long period of solar radiation.*				P4
Open Spaces and Built form		*Open spaces such as courtyards and atria must be used to act as heat sinks during the day and radiate the heat back at night.*				P5
		Grasses must be used in the open spaces (courtyards) act as ground cover to absorb solar radiation and aid evaporative cooling.				P6
Orientation and Plan form		*The orientation of building plan must be such that its longest sides are preferred facing N-S directions.*				P7
		The surface to volume (S/V) ratio is kept as minimum as possible to reduce heat gains. It is achieved by decreasing the surface of the building exposed to the outside.				P8
Building Envelope	*Roof*	*Flat roofs or vaulted roofs are ideal in this climate.*				P9
		Use is made of a massive material as the roofing sheet as having good insulative value.				P10
		The use of indoor ceilings having good insulation value is favourable as the space between the roof and ceiling acts as a heat buffer.				P11
		Evaporative cooling of the roof surface to allow for night time radiating cooling should be employed. In this case, it is				P12

		better to use a roof having high thermal transmittance.				
	Walls	*In multi-storied buildings, Well-insulated and very thick walls give a good thermal performance if the glazing is kept to a minimum and windows are well-shaded. A wall that transmits less heat is used.*				P13
	Fenestration	*-In hot and dry climates, reducing the window area lower indoor temperatures.* *-The heat gain through windows can also be reduced by using glass with low transmissivity*				P14
		More windows should be provided in the north and south facades of the building than the east and west as they receive lesser radiation throughout the year.				P15
		-All openings should be protected from the sun by using external shading devices such as chajjas and fins. *-Moveable shading devices such as curtains and venetian blinds are preferably used here.*				P16
		-Desert coolers and/or ventilators are extensively used in this climate, they are preferred at higher levels as they help in throwing out the hot air.				P17

		-Earth air pipe systems are effectively.				
		-The use of materials made of wood, stone or RCC materials in great proportion may be considered as they allow ventilation while blocking solar radiation.				P18
Colour and Texture		*-Use of colours that absorb less heat such as white should be made to paint the wall surfaces.* *-The surface of the wall should preferably be textured to facilitate self-shading and hence the lowering of indoor temperatures.*				P19
		-The surface of the roof should be reflective. Darker shades should be avoided for surfaces exposed to direct solar radiation.				P20
Special Considerations		*Deciduous trees are used to shade the building during hot weather and then admit sunlight in the dry harmattan. Harmattan is uncomfortably cold weather and requires windows be designed such that they encourage direct gain during this period.*				P21
		Indoor plants can be provided near the window, as they help in evaporative cooling and in absorbing solar radiation.				P22

Appendix II: (Thermal Comfort Questionnaire Survey)

(**Introduction**)

A thermal comfort survey is being conducted for this building as part of M.Sc. research thesis: *Bioclimatic Response in Design of Faculty of Environmental Sciences in the Hot-Dry Climate of Yobe State University, (YSU) Damaturu.* The survey relates specifically to the occupants' perceived thermal comfort. Your participation in the thermal comfort survey by answering these questionnaires accordingly is highly implored. You are required to tick ( ) your option according to your belief. Note that all survey responses will remain confidential. Participants will remain anonymous.

(**Basic Data**)

1. What is your gender?

	Male
	Female

2. What age range do you belong?

	15 – 30yrs
	30 – 45yrs

3. Name this building.

	Lecture Hall
	Classroom
	Laboratory

4. For how many hours do you stay in this building within the 24hours each day?

	Less than 6hours
	More than 6hours

5. How would you describe your purpose of staying in this building each day?

	Lectures
	Reading
	Other Reasons

(**Thermal Environment**)

6. Please tick the scale below at the place that best represents how you feel at this moment. You may tick in an appropriate place between two categories, if you wish.

	Cold
	Cool
	Slightly cool
	Neutral
	Warm
	Slightly warm
	Hot

7. Please select the box below that best represents how you feel at this moment (openings opened). I would like to be:

	Too hot
	Comfortable
	Too cold

8. Please select the boxes that best represent how you feel at the moment about the AIR MOVEMENT at this space.

	Very acceptable
	Moderately acceptable
	Slightly acceptable
	Slightly unacceptable
	Moderately unacceptable
	Very unacceptable

9. I would like:

	Moist air movement
	No change
	Dry air movement

10. (General Comfort) How comfortable is this indoor space right now?

	Very comfortable

	Moderately comfortable
	Slightly comfortable
	Slightly uncomfortable
	Moderately uncomfortable
	Very uncomfortable

11. (Temperature) What would you estimate the temperature at your space to be RIGHT NOW?

Temperature	(°C)

12. (Activity) What activities have you been engaged in during the preceding hour?

	Sitting reading	Sitting typing	Standing still	On feet working	exercising	Walking around
Last 10 minutes?						
The last 10 minutes preceding?						
The 10 minutes before that?						
The half hour before that?						

13. (Inlayer clothing) Please indicate whether you are wearing any of the items listed below in this space normally to adjust the thermal discomfort.

	Not wearing item	Light weight item	Medium weight item	Heavy weight item
Short sleeve shirt				
Long sleeve shirt				
Pants				

Shorts				
Dress(women)				
Skirt(women)				

14. (outer layer clothing) Please indicate whether you are wearing any of the items listed below in this space normally to adjust the thermal discomfort.

	Not wearing item	Light weight item	Medium weight item	Heavy weight item
Sweater				
Vest				
Jacket				

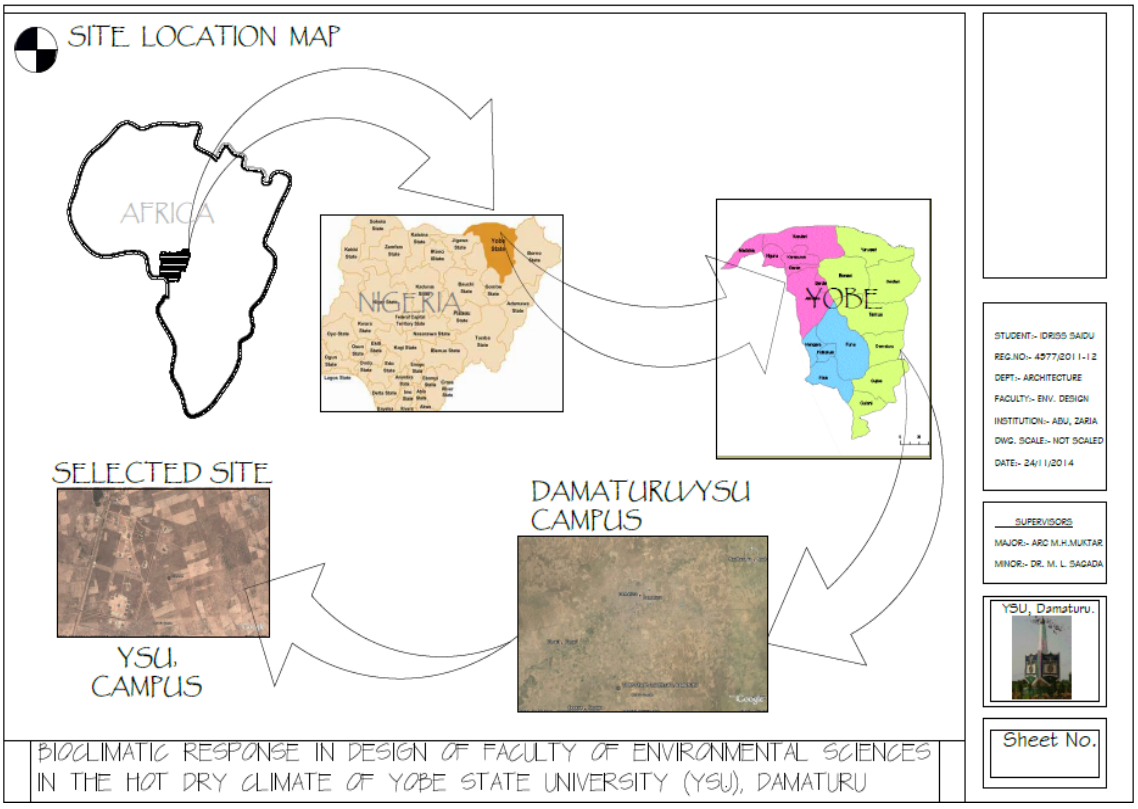
15. At this moment are you wearing more/less clothing at this indoor space than you prefer/expect?

	More clothes than wanted
	Ok
	Less clothes than wanted

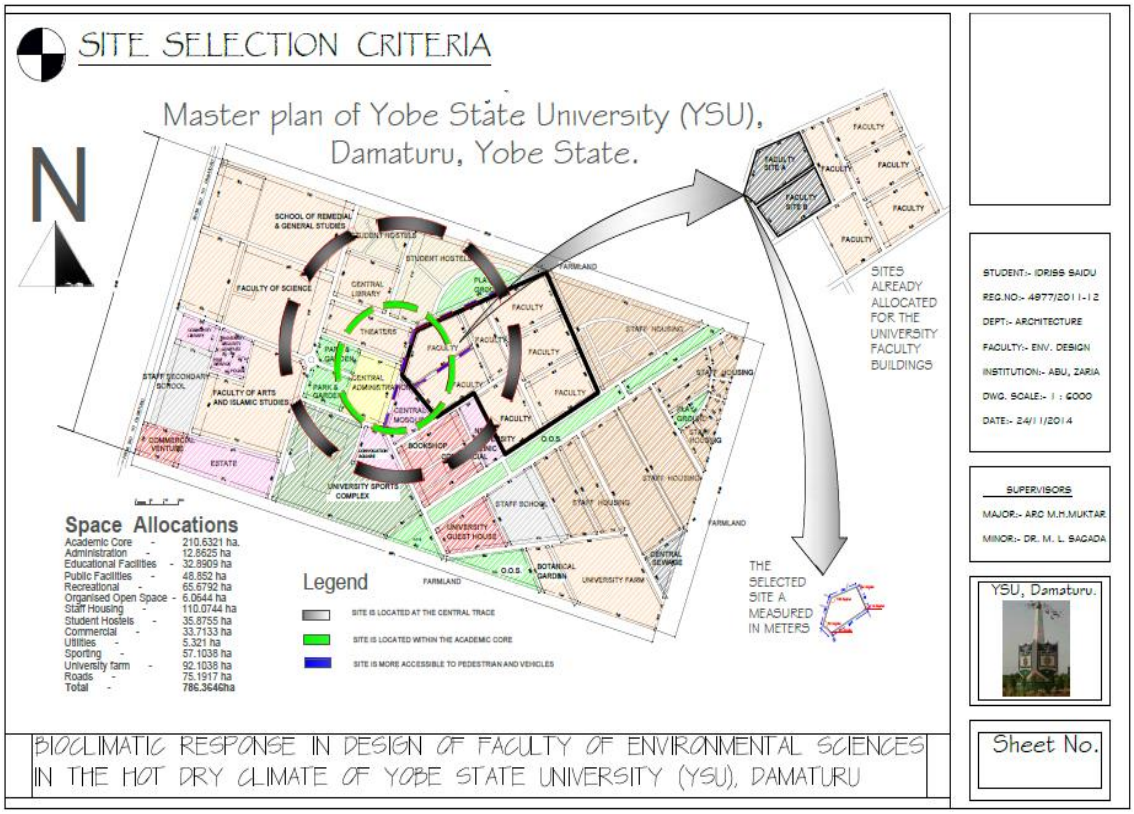
16. How much time do you expect to spend in this indoor space during this week?

	Minutes/Hour/Days

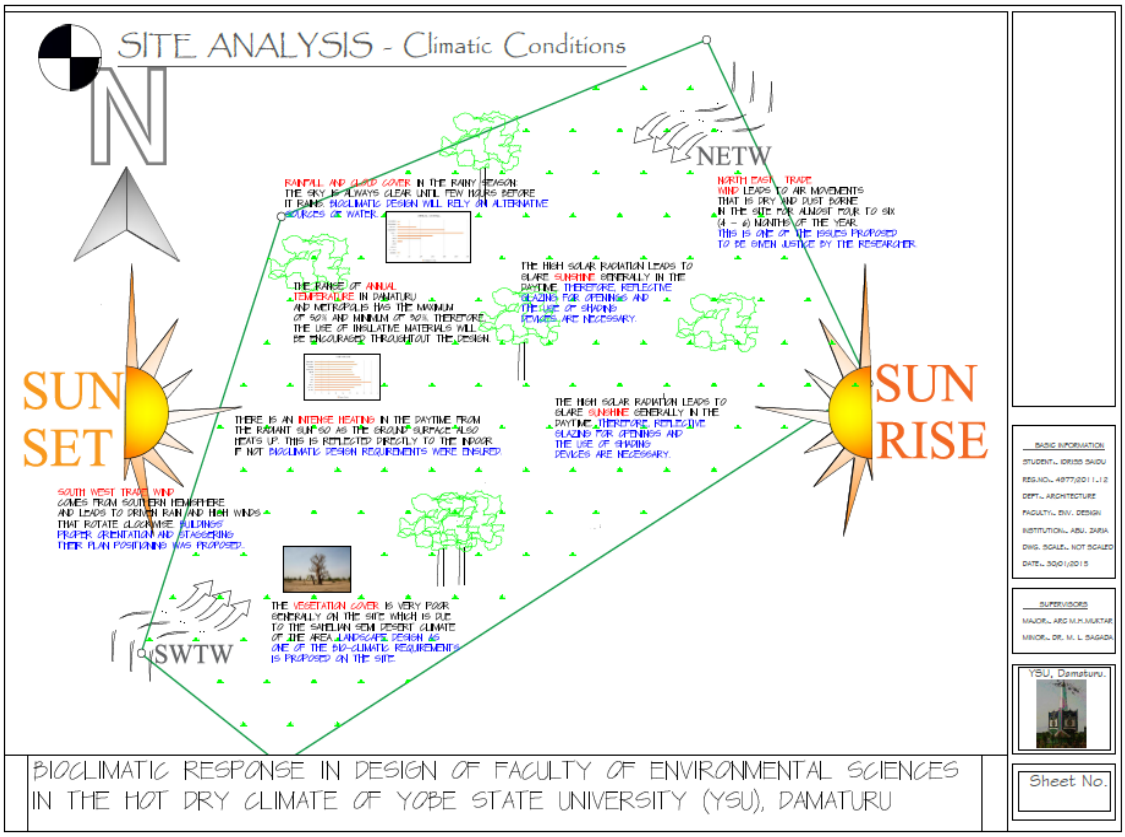
Appendix III: (Researcher's Designed Sheets)



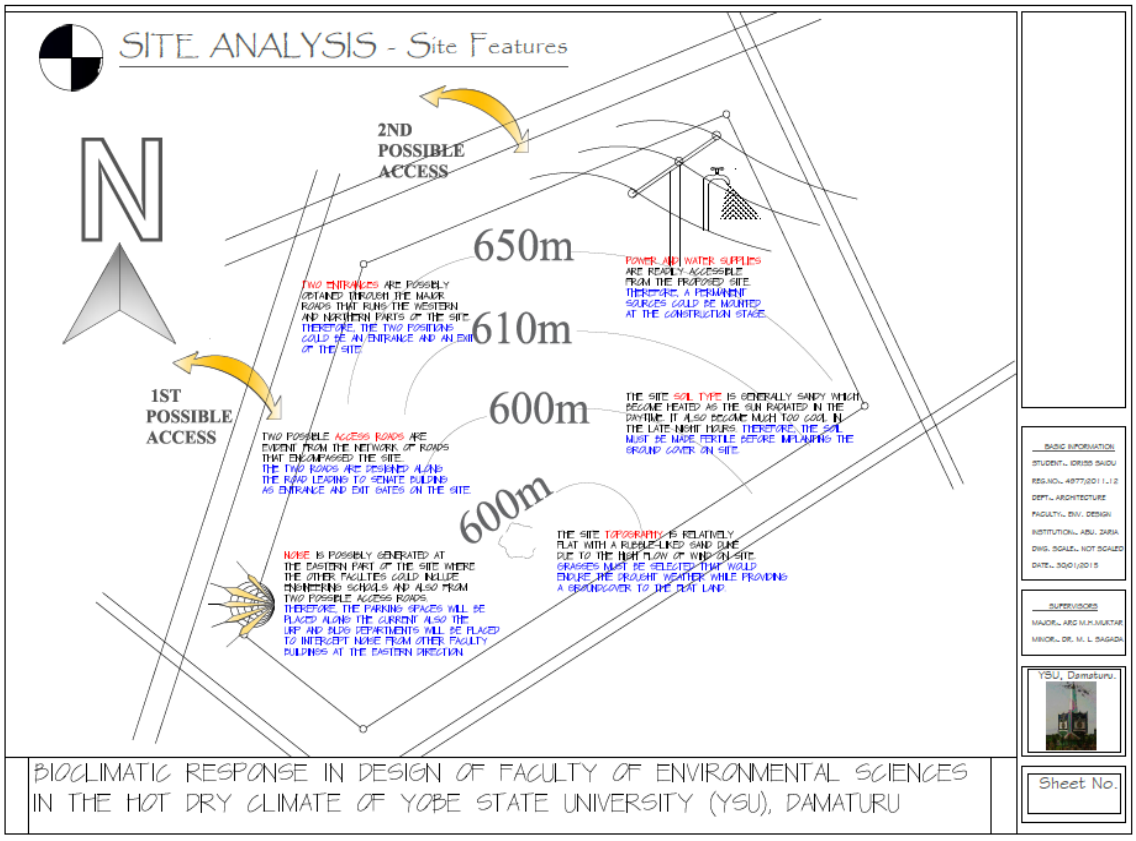
Appendix IIIa: Site Location Map



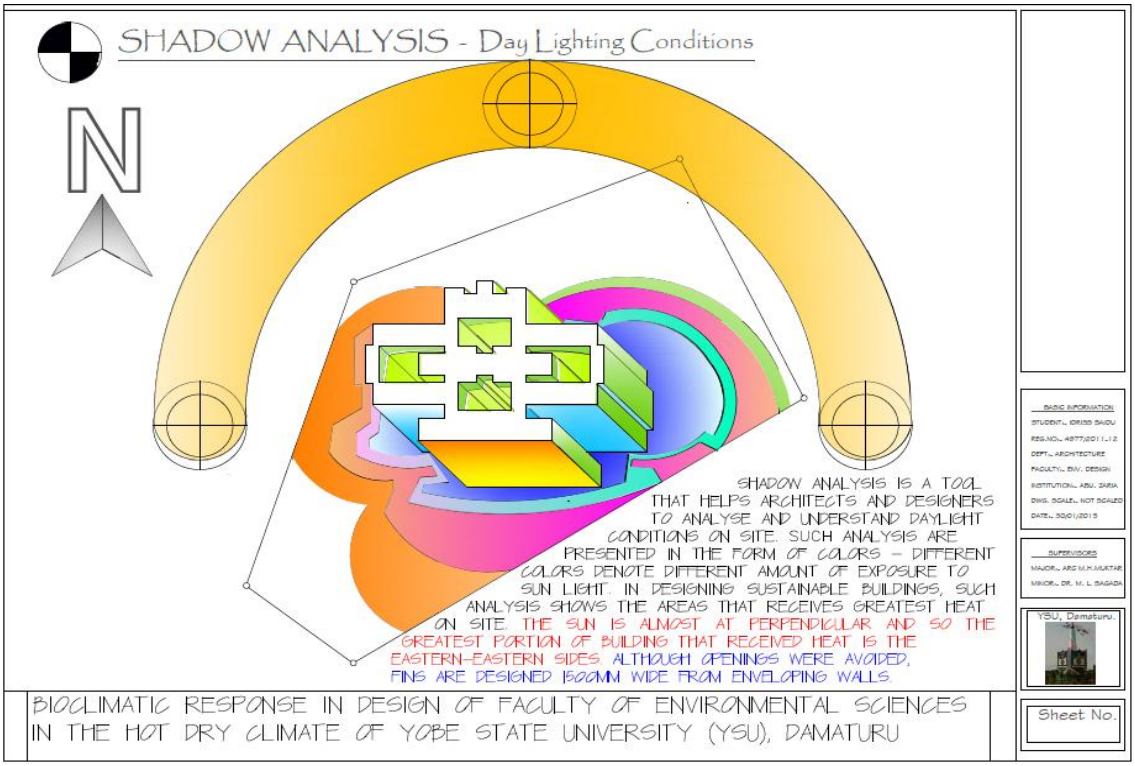
Appendix IIIb: Site Selection Criteria



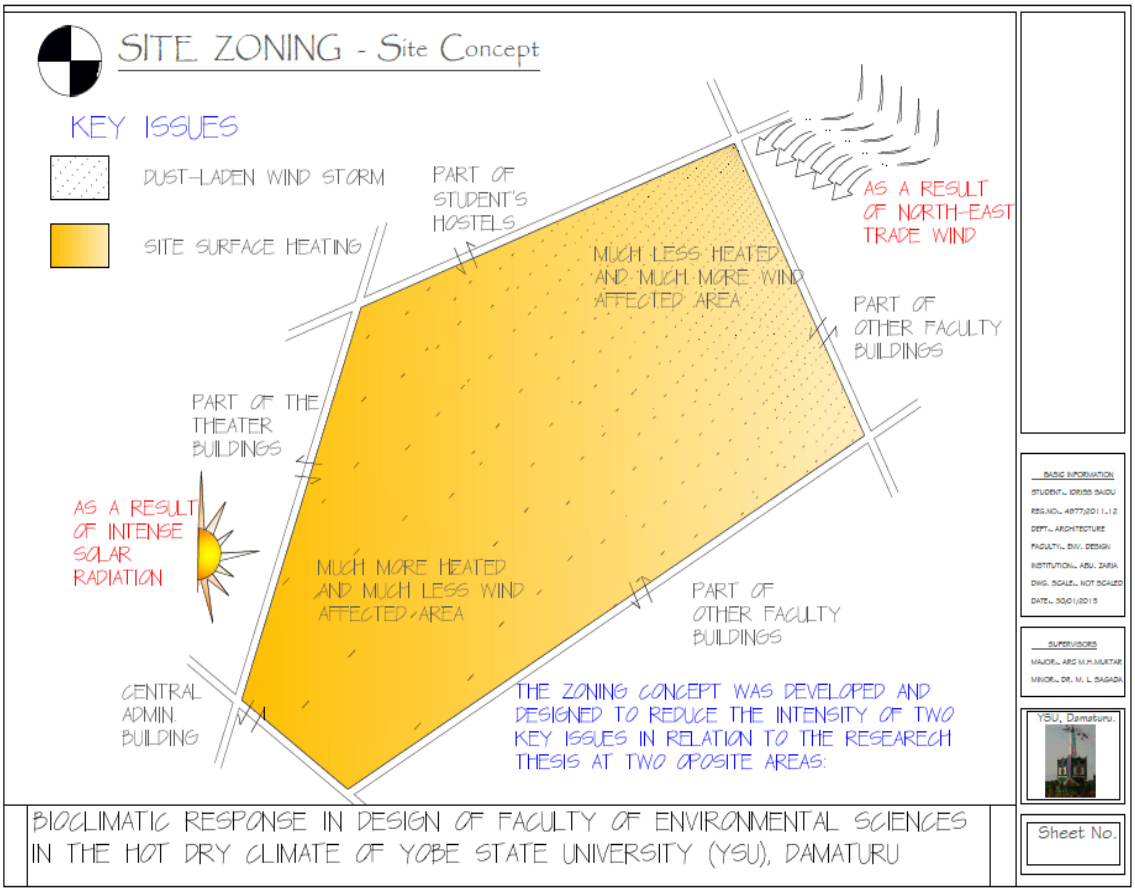
Appendix IIIc: Climatic Site Analysis



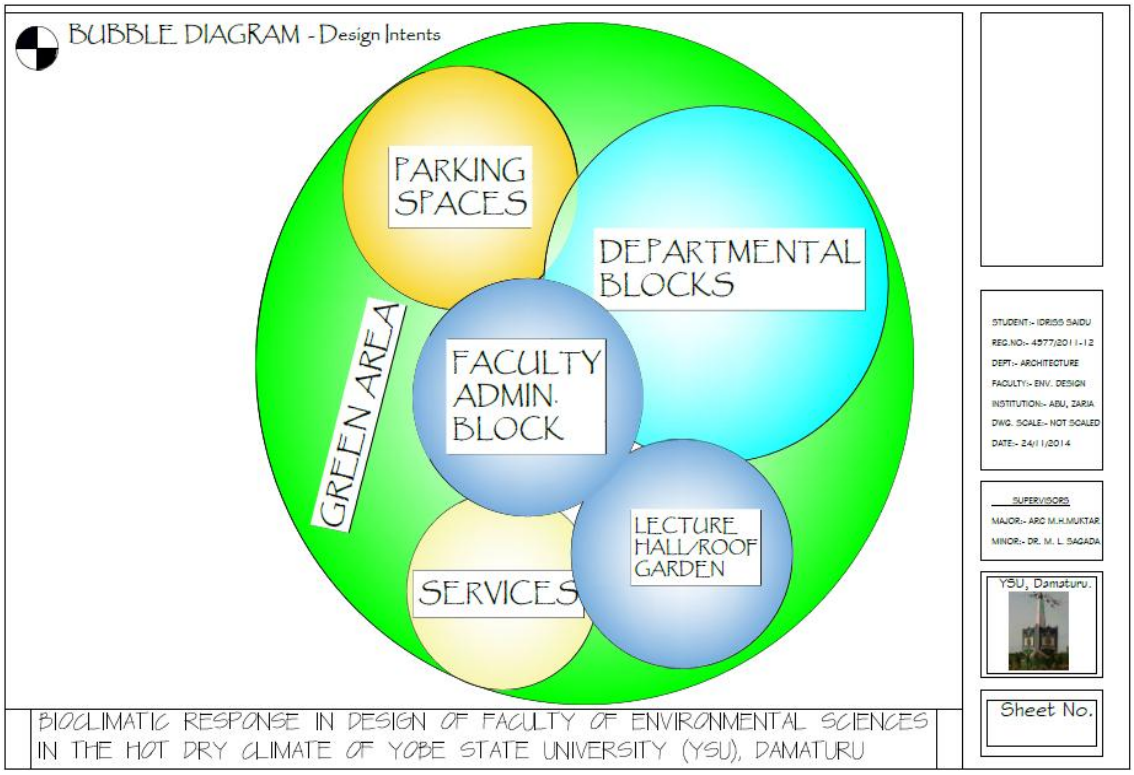
Appendix IIId: Site Features Analysis



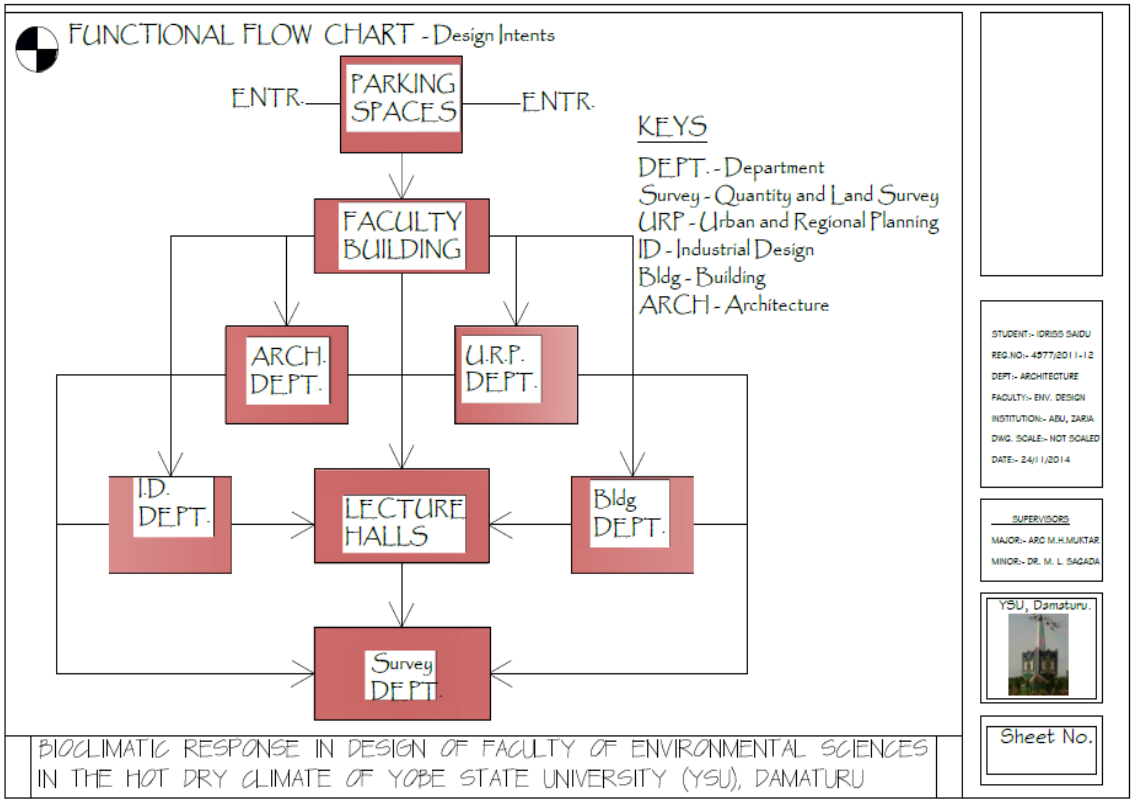
Appendix IIIe: Site Shadow Analysis



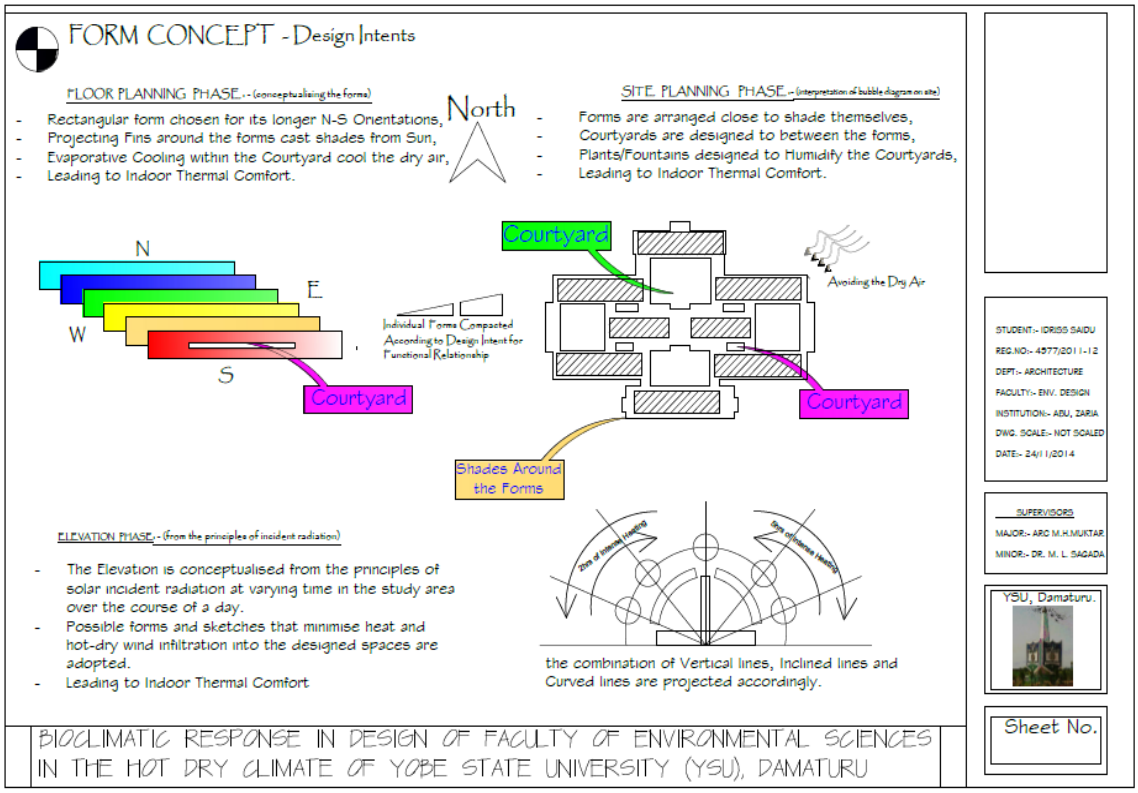
Appendix IIIf: Site Zoning



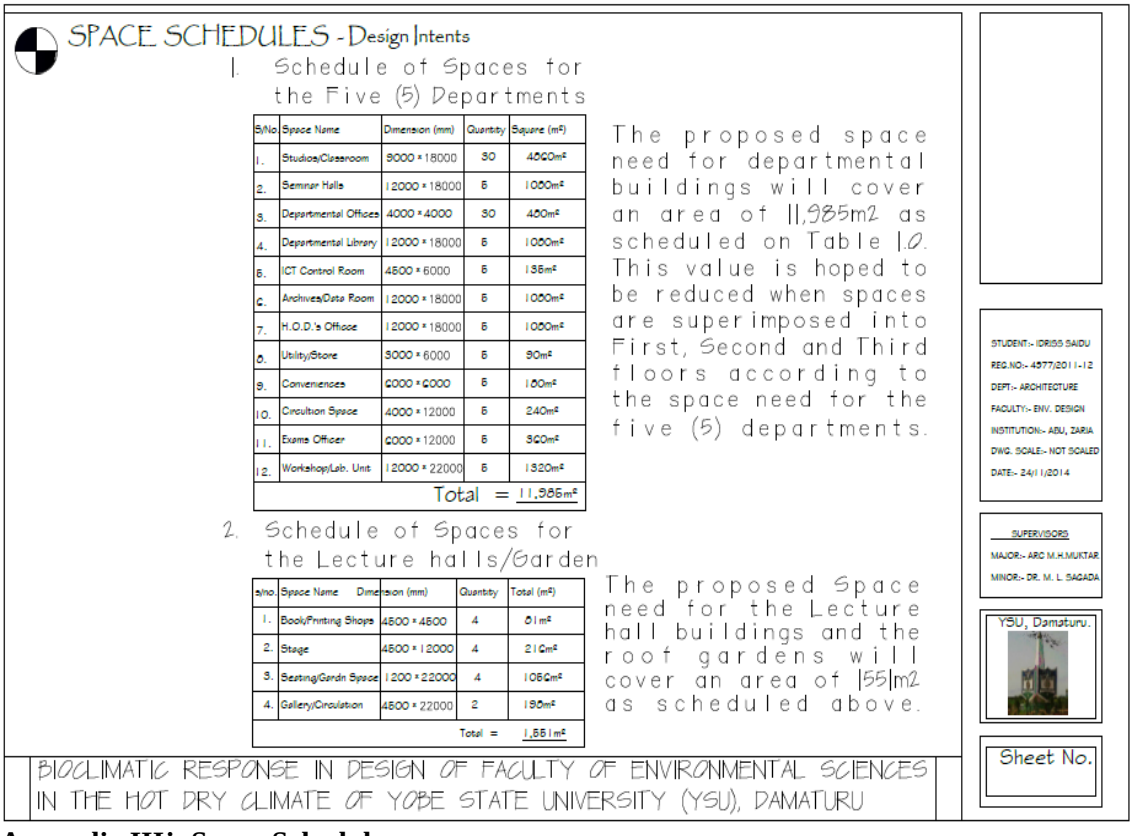
Appendix IIIg: Bubble Diagram of Functions on Site



Appendix IIIh: Functional Flow Chart



Appendix IIIi: Form Concepts on Site



Appendix IIIj: Space Schedules

SPACE SCHEDULES - Design Intents

3. Schedule of Spaces for the Faculty Building

s/no.	Space Name	Dimension (mm)	Quantity	Total (m²)
1.	Deans' Office	4800 × 12000	1	54m²
2.	Faculty Library	9000 × 9000	1	81m²
3.	Faculty Exhibition Rm	9000 × 9000	1	81m²
4.	Faculty Offices	3000 × 3000	16	144m²
5.	Conference Room	9000 × 9000	1	81m²
6.	I.C.T. Control Room	4800 × 12000	1	54m²
7.	Data Room	9000 × 9000	1	81m²
8.	Maintenance Office	4800 × 12000	1	54m²
9.	Faculty Store	4800 × 12000	2	54m²
10.	Conveniences	3000 × 9000	8	216m²
11.	Circulation Space	4000 × 15000	4	240m²
12.	Gallery/Reception	9000 × 9000	4	324m²
13.	External Defence Rm	4800 × 12000	2	108m²
14.	PG Coordinator	4800 × 12000	1	54m²
12.			Total =	1,626m²

The proposed space need for the faculty block will cover an area of 1626m2 as scheduled above.

Therefore:

11,985m2
+ 1,551m2 = 13,162m2
1,626m2

Now, if the Site Size is given as 47543m2; then Proposed Faculty will cover the area of about 32% of the site. When the departmental buildings are superimposed into Ground floor, First floor, Second floor and Third floor; then this will be reduced to only cover an area of 12% out of the total site.

s/no.	Space Name	Percentage Covered	Area Covered
1.	Proposed Project	12%	5,705.16m²
2.	Parking Spaces	20%	9,508.6m²
3.	Green Area	40%	19,017.2m²
4.	Potential Expansion	28%	13,312.04m²

STUDENT:- IDRISS SAIDU
REG.NO:- 4577/2011-12
DEPT:- ARCHITECTURE
FACULTY:- ENV. DESIGN
INSTITUTION:- ABU, ZARIA
DWG. SCALE:- NOT SCALED
DATE:- 24/11/2014

SUPERVISORS
MAJOR:- ARC M.H.MUKTAR
MINOR:- DR. M. L. SAGADA

YSU, Damaturu.



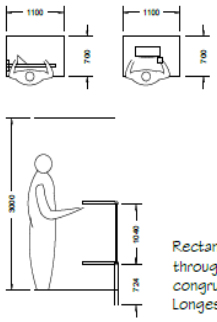
Sheet No.

BIOCLIMATIC RESPONSE IN DESIGN OF FACULTY OF ENVIRONMENTAL SCIENCES IN THE HOT DRY CLIMATE OF YOBE STATE UNIVERSITY (YSU), DAMATURU

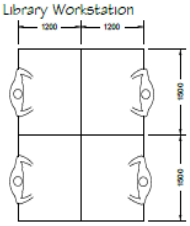
Appendix IIIk: Space Schedules continues

SPACE ANALYSIS - Design Intents

Studio/Office Workstation



Library Workstation



Rectangular Shapes has been employed throughout the design because of it is congruent with the research provisions for Longest side to face N - S direction.

Planning Data (Conference/Lecture Hall)

s/no.	Plan Shape	Seats Capacity	Circulation Space
1.	Square	240	Normal
2.	Circular	180	Abnormal
3.	Rectangular	250	Normal
4.	V - Shaped	180	Abnormal

Planning Data (Number of Staff Offices)

s/no.	Case Buildings	Arch.	Bldg	I.D.	URP	EMT	Surv.	Geo
1.	ATBU, Bauchi	16	8	15	14	-	13	16
2.	MAUT, Yola	24	14	-	15	14	15	-
3.	PROPOSALS	30	20	20	20	-	20	-

Planning Data (Number of Students/Studio Space need)

s/no.	Case Buildings	Arch.	Bldg	I.D.	URP	EMT	Surv.	Geo
1.	ATBU, Bauchi	40	30	20	30	-	40	40
2.	MAUT, Yola	40	30	-	30	30	40	-
3.	PROPOSALS	60	40	30	40	-	30	-

Corridor/Verandah Width in order to accommodate heavy crowd of students

3000

900 High Level Window 900mm high at 2100mm from the floor level

900 Low Level Window 900mm high at 300mm from the floor level

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INSTITUTION:- ABU, ZARIA
DWG. SCALE:- NOT SCALED
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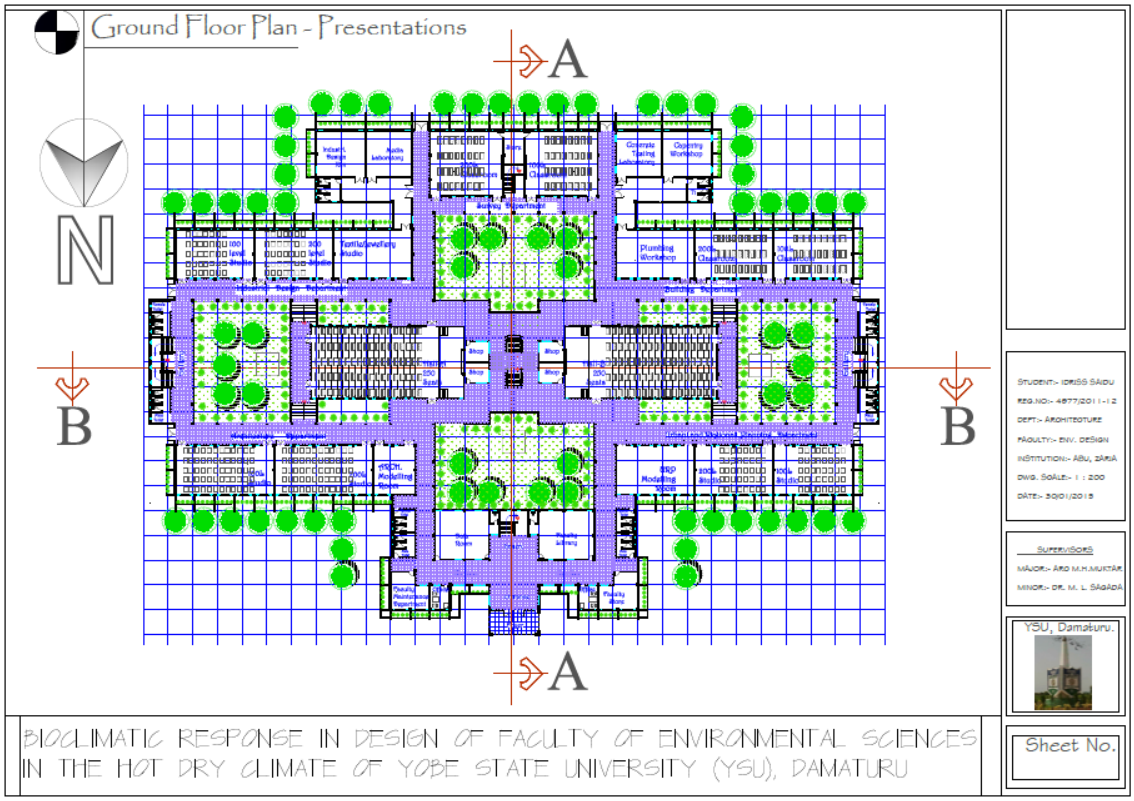
YSU, Damaturu.



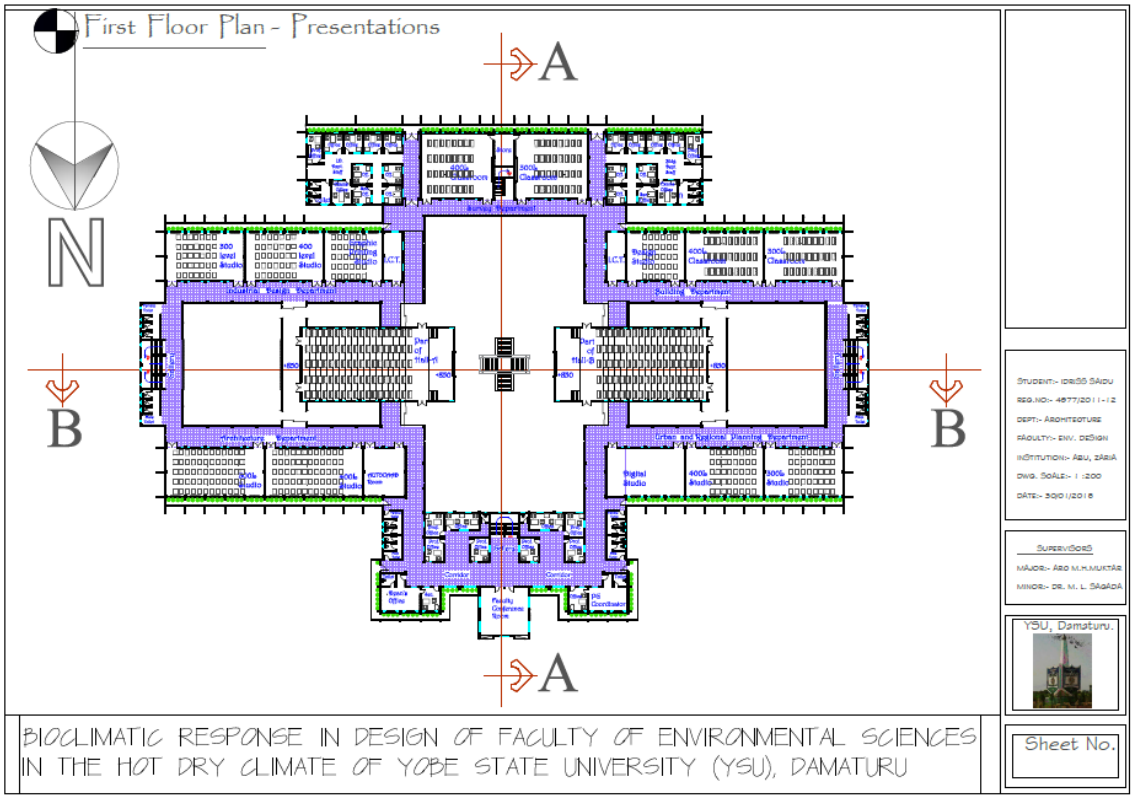
Sheet No.

BIOCLIMATIC RESPONSE IN DESIGN OF FACULTY OF ENVIRONMENTAL SCIENCES IN THE HOT DRY CLIMATE OF YOBE STATE UNIVERSITY (YSU), DAMATURU

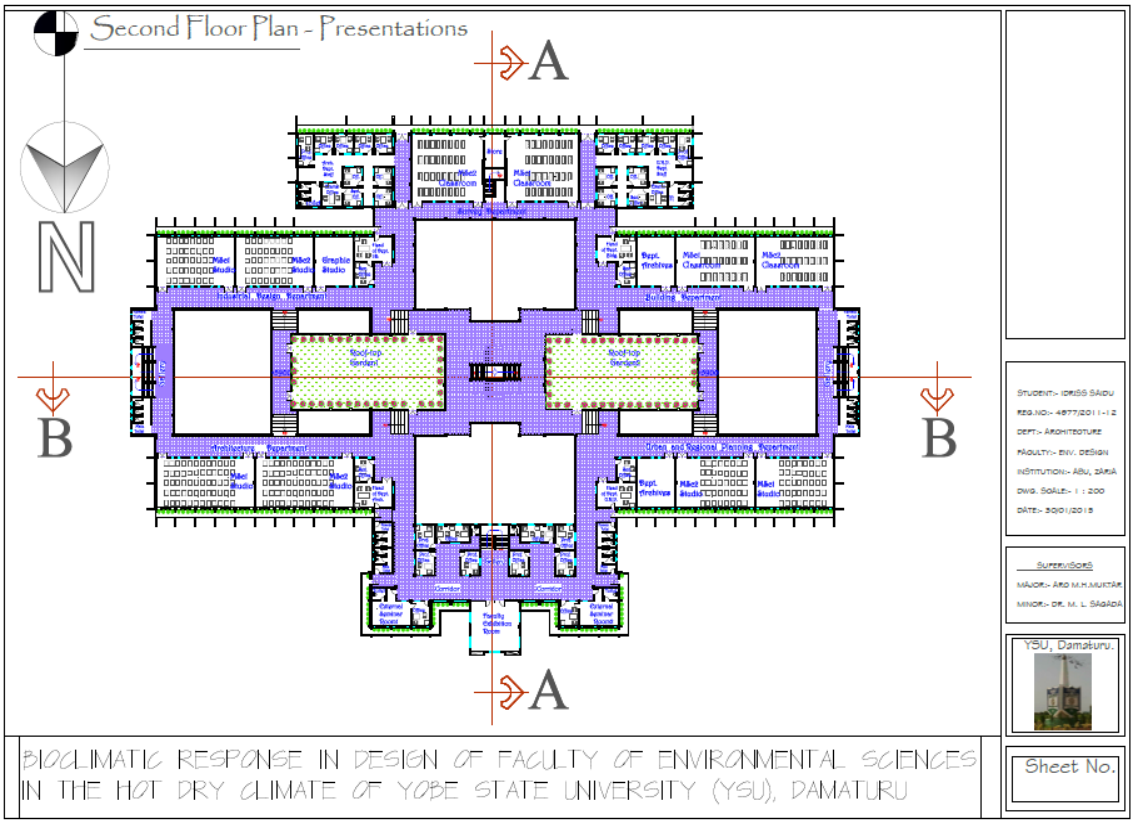
Appendix IIIl: Space Analysis



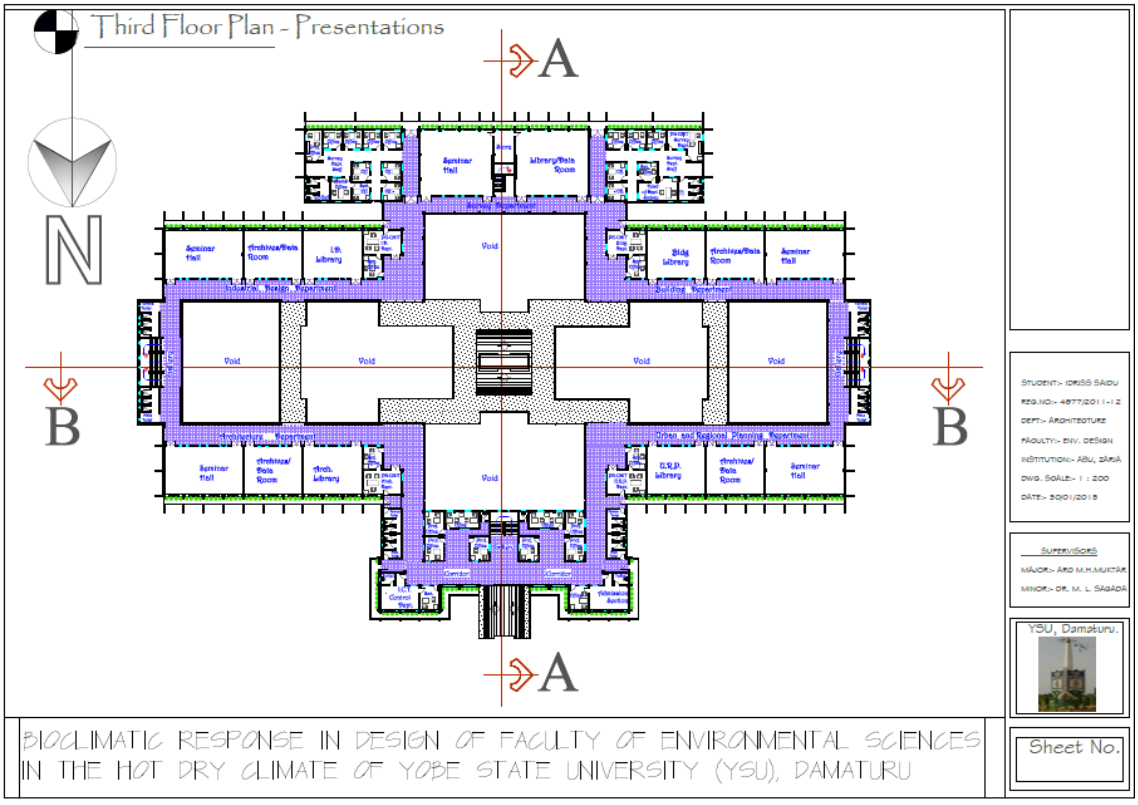
Appendix IIIm: Ground Floor Plan



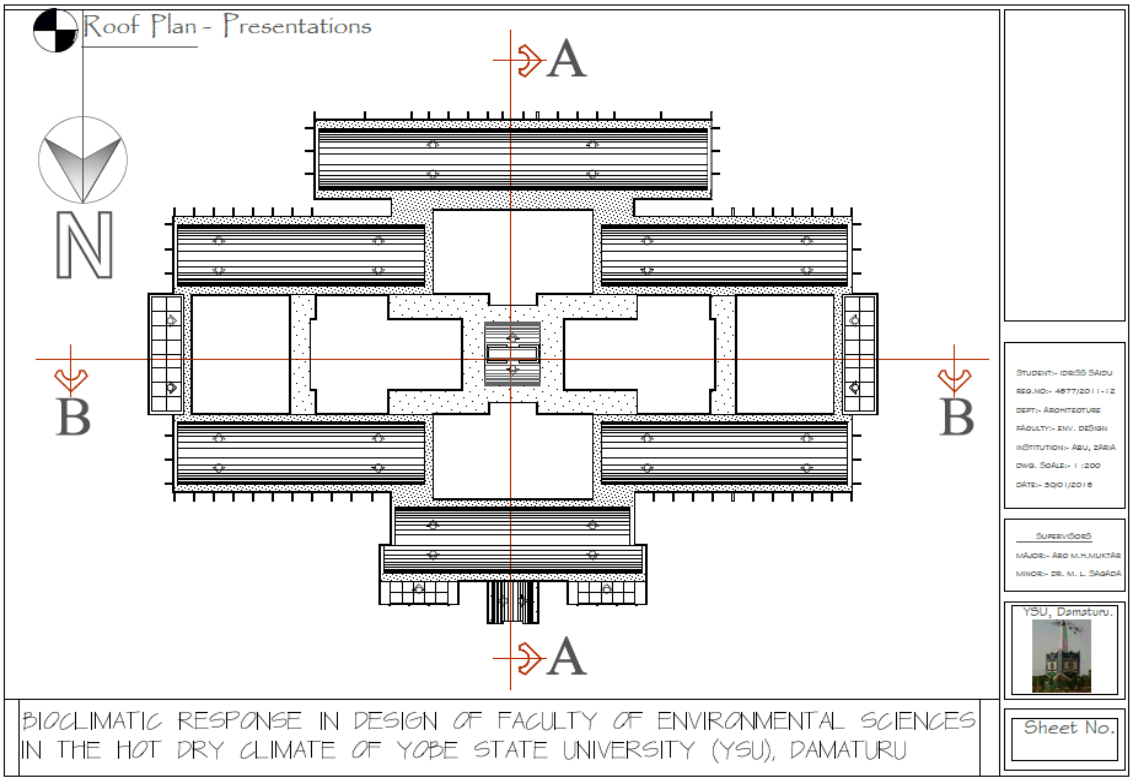
Appendix IIIn: First Floor Plan



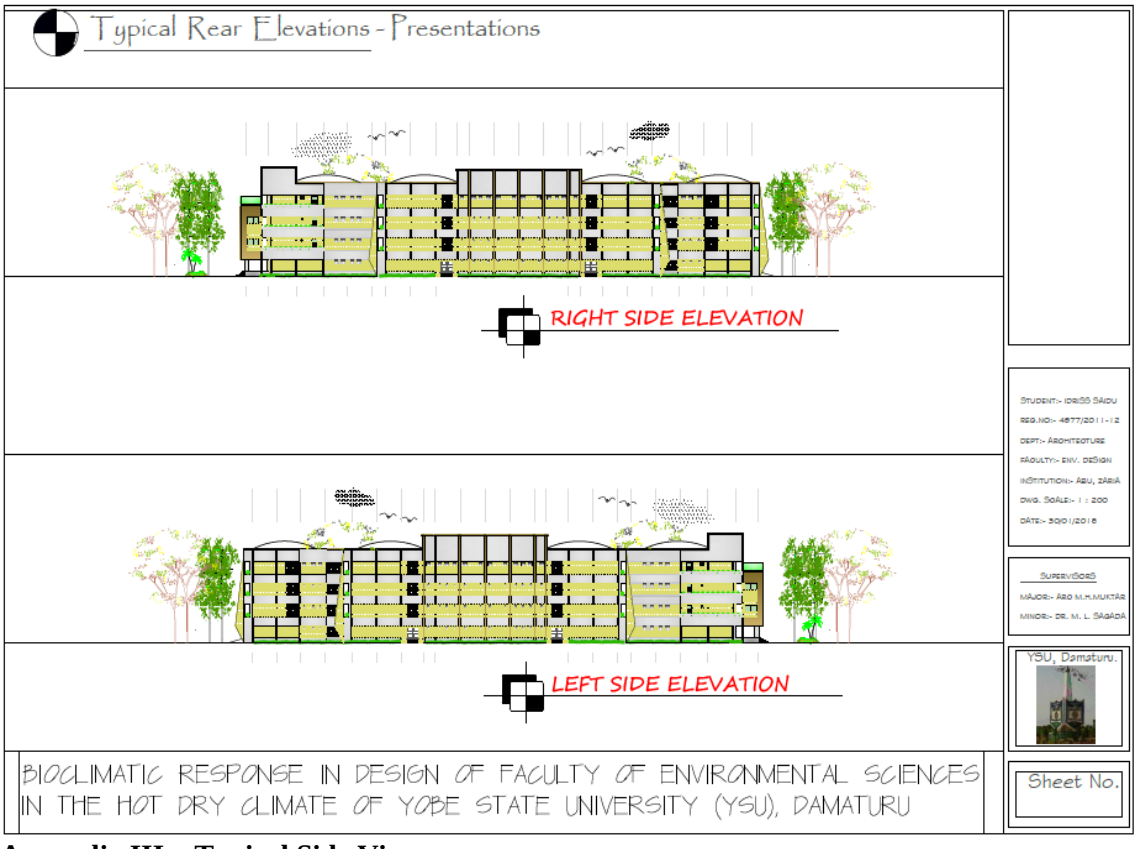
Appendix IIIo: Second Floor Plan



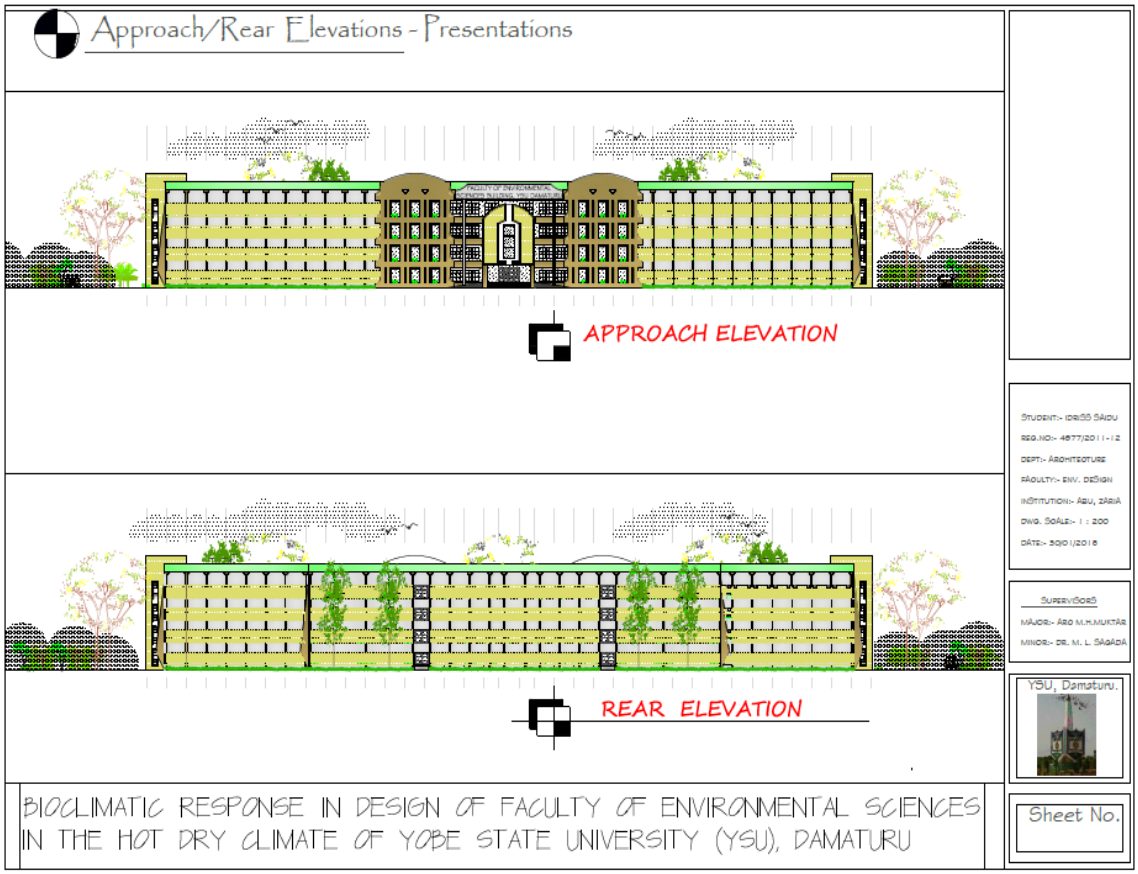
Appendix IIIp: Third Floor Plan



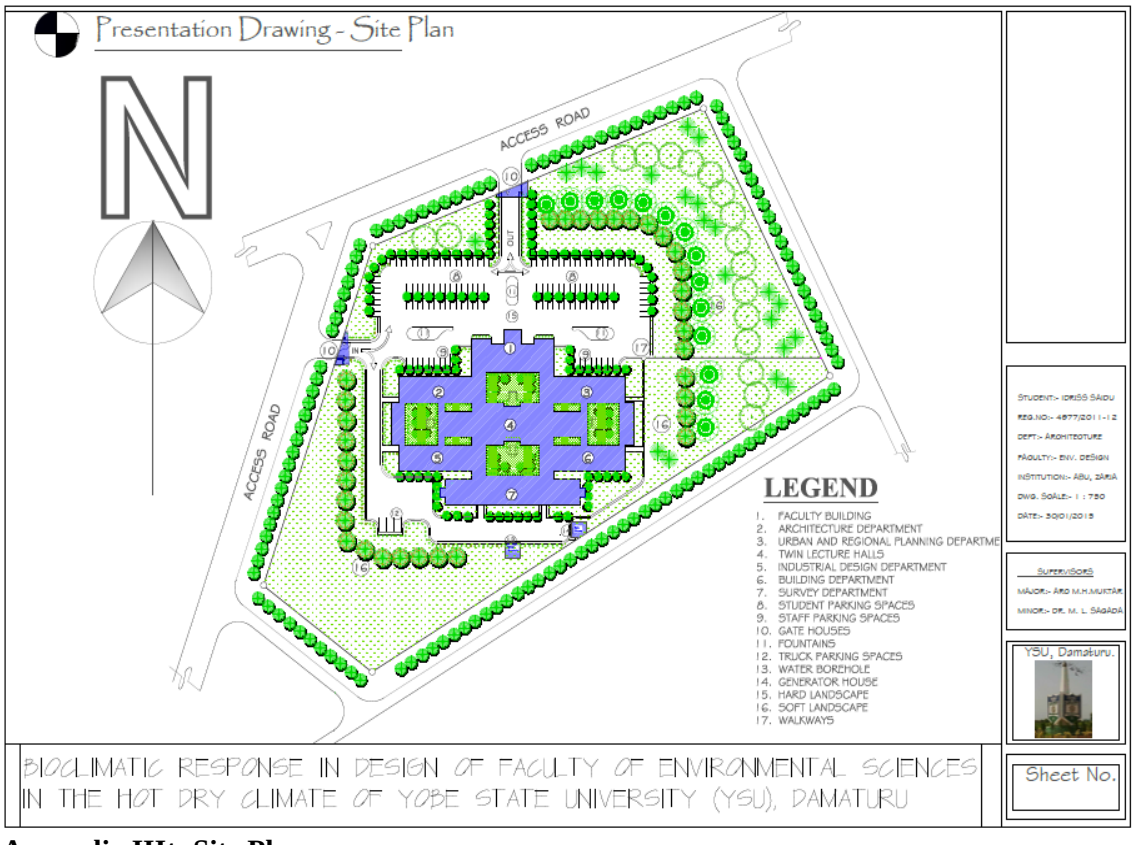
Appendix IIIq: Roof Plan



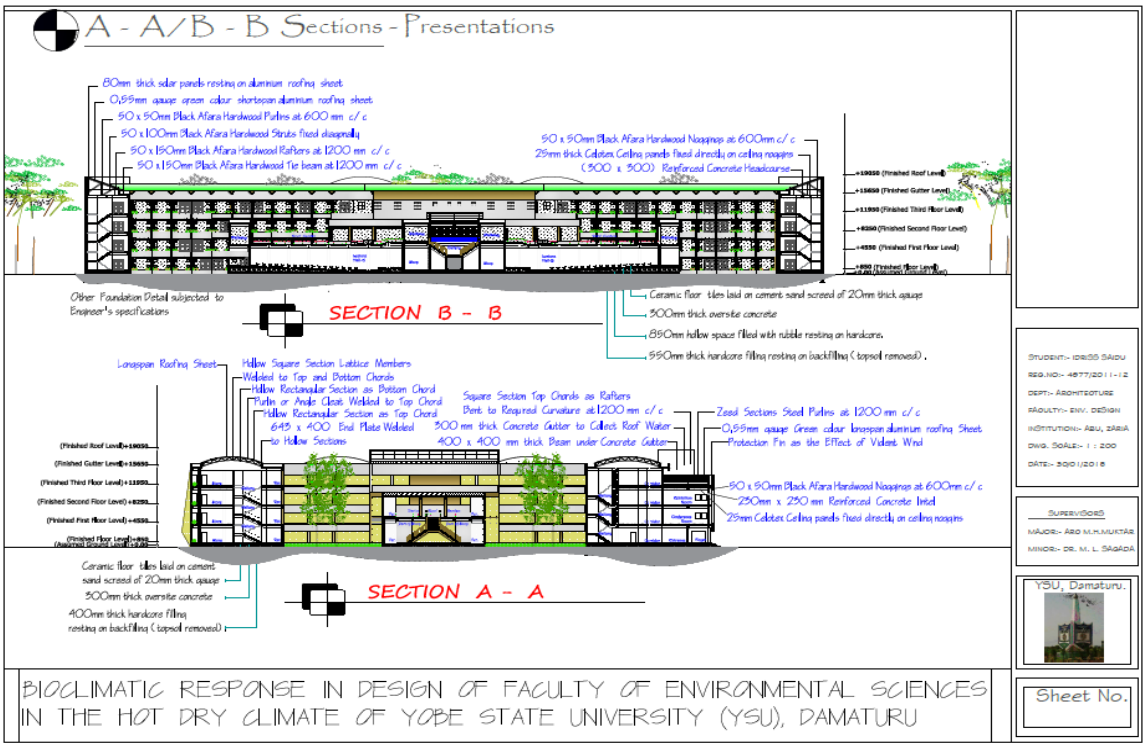
Appendix IIIr: Typical Side Views



Appendix IIIs: Approach and Rear Views



Appendix IIIt: Site Plan



Appendix IIIj: Sections A-A and B-B



Appendix IIIk: Three Dimensional View (3D)