Testing and evaluation of a newly installed Agrometeorology Instrumentation Mast (AIM) web-based system in a rural school in Swayimana, KwaZulu-Natal, South Africa

by

ZIBUYILE DLAMINI

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School of Agricultural, Earth and Environmental Sciences

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PREFACE

The research contained in this dissertation was completed by the candidate while based in the Discipline of Agrometeorology, School of Agricultural, Earth and Environmental Sciences of the College of Agriculture, Engineering and Science, University of KwaZulu-Natal, Pietermaritzburg, South Africa. The research was financially supported by component one of the UMngeni Resilience Project.

The contents of this work have not been submitted in any form to another university and, except where the work of others is acknowledged in the text, the results reported are due to investigations by the candidate.

Signed: Professor Michael John Savage

Date: 5th March 2019

DEDICATION

To the budding scientists of Swayimana High School.

DECLARATION 1: PLAGIARISM

I, Zibuyile Dlamini, declare that:

(i) The research reported in this dissertation, except where otherwise indicated or acknowledged, is my original work;

(ii) This dissertation has not been submitted in full or in part for any degree or examination to any other university;

(iii) This dissertation does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons;

(iv) This dissertation does not contain other persons' writing, unless specifically acknowledged as being sourced from other researchers. Where other written sources have been quoted, then:

a) Their words have been re-written but the general information attributed to them has been referenced;

b) Where their exact words have been used, their writing has been placed inside quotation marks, and referenced;

(v) Where I have used material for which publications followed, I have indicated in detail my role in the work;

(vi) This dissertation is primarily a collection of material, prepared by myself, published as journal articles or presented as a poster and oral presentations at conferences. In some cases, additional material has been included;

(vii) This dissertation does not contain text, graphics or tables copied and pasted from the Internet, unless specifically acknowledged, and the source being detailed in the dissertation and in the References sections.

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Signed: Zibuyile Dlamini

Date: 5th March 2019

DECLARATION 2: PUBLICATIONS

The research reported on is based on the data I collected from the scholars who were introduced to the Agrometeorological Instrumentation Mast (AIM) in Swayimana. I designed the experiments, collected, analysed the data and wrote the paper. The establishment of the Agrometeorology Instrumentation Mast (AIM) system would not have been possible without assistance from the Agrometeorology postgraduates and technical staff.

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Signed: Zibuyile Dlamini

Date: 5th March 2019

ABSTRACT

Rural communities in South Africa are the most vulnerable to the effects of climate change and adverse weather due to their heavy reliance on natural resources. Agricultural adaptation is therefore essential. However, there is very little evidence of efforts to build the capacity of rural communities to adopt climate-smart agricultural and environmental practices. Education and public awareness on a community scale are the most important strategies for dealing with climate change and adverse weather. Climate change and adverse weather communication both present challenges because of their complexities. An Agrometeorology Instrumentation Mast (AIM) system was installed at Swayimana High School in Swayimana near Wartburg in KwaZulu-Natal, South Africa. The AIM system is unique in South Africa and was developed to enhance teaching and learning and facilitate research. The system was installed to provide the scholars with real-time weather data and weather hazard warnings using selected information and communication technology (ICT) methods. The emphasis is placed on the use of visualisation to simplify complex elements of adverse weather by displaying measurements graphically.

The aim of this study was to investigate whether using the AIM system is an effective tool to promote agrometeorological literacy and over time improve adverse weather resilience in Swayimana. It explores how the web-based system enhances scholars learning and their response to it. It also investigates scholars' attitudes and perceptions of climate variability and climate change. The target sample was scholars of Swayimana High School in Grades 10 to 12. A combination of purposive and simple random sampling was used to select the participants. Predominantly qualitative research methods were used to obtain an understanding of opinions and perceptions. Content and descriptive analysis was employed to analyse open-ended questionnaires and group interviews.

The baseline study conducted demonstrated that scholars felt adverse weather was an important issue but that they were not aware but were poorly equipped to adapt to adverse weather. A lack of computer literacy presented a challenge for scholars when using the system at the school. The alternative option of accessing the website through a web-enabled phone proved to be of advantage. The system improved their understanding of technical and scientific terms that were absent in their language. Web-based learning encouraged critical thinking, active participation in lessons ability to read and analyse visual representations of statistical data. Further, the system improved their awareness of adverse weather, global climate variability and change and adaptation strategies. The results demonstrated the attractiveness of the AIM system as an education tool. However, there is a need for a much larger and longer-term research study on the usability of the system.

Keywords: *climate change adaptation, climate change communication, climate resilience, climate-smart agriculture, climate change, climate variability, information and communication technologies (ICT), visualisation, visual literacy*

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Psalms 95 4-5. In his hand are the depths of the earth, and the mountain peaks belong to him. The sea is his, for he made it, and his hands formed the dry land.

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CHAPTER 1: INTRODUCTION

1.1 Background

Climate change is the gradual shift in climate systems evident in the change in global weather patterns (Mavi and Tupper 2004). Atmospheric changes include an increase in air temperature, a higher frequency and length of droughts and dry spells, decrease in rainfall predictability coupled with an increase in rainfall intensity (Below et al. 2010; Nwobodo and Agwu 2015) These changes produce secondary agricultural and environmental effects, which further have socio-economic implications (Below et al. 2010; Nwobodo and Agwu 2015). Climate change is therefore deemed the most threatening phenomenon facing humankind and needs to be aggressively addressed (Pumphrey 2008; Gautam 2013).

Rural communities, especially in Africa, are counted as those most vulnerable to climate change effects as they are directly dependent on agricultural and natural resources (Nwobodo and Agwu 2015). Smallholder farmers are amongst the group most vulnerable to the effects of climate change. Adaptation is, consequently, essential in rural communities in order to improve climate resilience. Climate resilience is the ability to absorb the stresses resulting from climate change without being severely affected. Youth have been identified as possible drivers of resilience because of their potential to influence rural development, agriculture and natural resource management in the future (Akinnifesi 2013).

Studies show that a lack of awareness of climate change contributes to reduced implementation of micro-level climate change adaptation strategies (Enete et al. 2011; DEA 2012). Schipper et al. (2010) defined climate adaptation strategies as methods used to adjust to new climate induced stresses and pressures. An inadequate amount of effort is being invested in creating climate change awareness. There is very little evidence of efforts to build the capacity of rural communities to adopt best agricultural and environmental practices or climate-smart agricultural practices. Climate-smart agriculture is defined as the sustainable transformation of agricultural systems to withstand the pressures of climate change (Lipper et al. 2014). Rural youths' limited interest in agriculture further exacerbates the problem because of the important role they could potentially play in implementation of adaptation strategies (Akinnifesi 2013). In addition, climate change communication presents challenges because of its complexities, uncertainty, climate system lags, and psychosocial factors that affect laypeople and communication limits on scientists. This plays a part in inhibiting involvement of the layperson and makes increased climate change awareness more difficult (Wibeck 2013; Monroe et al. 2015).

Society is increasingly becoming more visually oriented, mainly due to rapid scientific and technological advancements. Visual imagery has previously largely been used in the different forms of media for entertainment, to stimulate interest in a certain topic or for recording information. Subsequently, it has become an essential part of communication as well as education, more so than language. Visualisation is widely used in science and technology education in order to display technical or difficult subject matter (Lowe 2000). Visual imagery is also employed in climate change science to better explain its complexities (Wibeck 2013).

A barrier to learning/understanding climate change science is language as the most common medium of learning is English in South Africa. Non-English speakers have difficulties learning in the English language because technical and scientific concepts/terms are more difficult to grasp (Oyoo 2015). Scholars are presented with a twofold challenge of having to grasp scientific terms they have no concept of and learn them in an unfamiliar language. Researchers believe that this is the most significant factor contributing to black South African scholars' poor academic performance (Ridge et al. 1997; van de Berg et al. 2011). Savage (2014) found that university scholars preferred to be taught in English rather than their home languages because technical terms that describe important aspects of climate and the environment are absent in South African local/indigenous languages and dictionaries. Subject matter in science disciplines such as Agrometeorology is difficult to grasp to a non-English speaker. Visualisation can be used to support language learning, by helping scholars link technical words with familiar concepts. Visuals force scholars to extend their language abilities because of their potential to encourage more complex language use (Baker 2015).

The Agrometeorology Instrumentation Mast (AIM) system is a web-based system, unique in South Africa, located at the University of KwaZulu-Natal (UKZN), Pietermaritzburg campus, South Africa. The system is used for agro-environmental teaching, learning and research. The intention for its development was to ultimately simplify agrometeorology and related disciplines. It can be described as an ICT (information and communication technologies) visualisation tool because it fundamentally transfers agro-environmental concepts and data into images for better understanding. It has proven to be an exceptional learning tool at UKZN as feedback from surveys conducted of scholars and staff was positive (Savage 2014; Savage et al. 2014). Its success is attributed to its use of visual literacy, which is the ability to read, analyse and understand graphics. Further, it made agrometeorology and other earth science based disciplines easier to relate to (Savage 2014; Savage et al. 2014).

Agrometeorology, an applied science, offers a considerable opportunity for understanding climate change concepts as it studies atmospheric components, their changes, their influence on agricultural elements and adaptation strategies **(**Lomas et al. 2000). It consequently contributes to research and the expansion of the body of knowledge of climate change science. Despite agrometeorology possessing so much potential, Hollinger (1994) found that the discipline experiences many growth difficulties. These difficulties can be attributed to a few noteworthy factors, particularly a declining number of scholars entering the field, retiring professionals and limited university finances to fund research.

1.2 Motivation for the study

Climate change is a cause for concern because of the threat it poses on rural communities' livelihoods for it places great stress on natural resources. Projected climate changes are reported to occur in the eastern parts of South Africa (UMngeni Resilience Project 2014). There has been an increase in the intensity and frequency of convective storms and floods, high air temperatures and other extreme weather events. Poor communities in the past decade have experienced damage to infrastructure, loss of assets and death (UMngeni Resilience Project 2014).

There is a need for interventions that recognize the importance of youth involvement in micro- (and macro-) agricultural adaptation implementation focusing on the interactions between climate change and agriculture. These interventions should ideally overcome climate change communication barriers to improve the adaptive capacity of rural communities to climate change. Literature suggests that public awareness and education strategies have often failed (Wibeck 2013). This study is part of a larger project (UMngeni Resilience Project) and recognises education at a community scale and dissemination of information as highly recommended strategies for responding sustainably to climate change.

An extension of the AIM system was installed at Swayimana High School, KwaZulu-Natal, South Africa. It consists of an automatic weather station (AWS) system along with supporting instruments in order to collect and display agrometeorological data to aid learning and to provide near real-time weather data. It seeks to simplify climate change education by using information and communication technologies (ICT) for visualisation. The system enables scholars to exercise existing visual literacy skills to help them grasp difficult concepts that cannot be expressed in their indigenous language. The system has proven to be an exceptional tool to enhance learning for otherwise difficult university disciplines. The logic behind the study is if understanding of climate change through learning is improved, there will be greater awareness, hence more involvement in implementation of adaptation strategies by the youth of Swayimana. Figure 1.1 is the image of the AWS installed in Swayimana.

Figure 2.1 The AWS installed in Swayimana (The automatic weather station taken at Swayimana High School in August 2017) Photo: Zibuyile Dlamini.

The AIM system potentially offers benefits for teaching and learning for climate change science and natural sciences. It could assist in improving the quality of science education in Swayimana High School and introduce agrometeorology to scholars earlier in their academic career, consequently igniting interest in the discipline. More importantly, it will help familiarise the scholars with some other concepts and terms used in natural science disciplines so that they are better prepared for university.

The research is experimental in nature as an AWS system has never been deployed, to our knowledge, to a rural school in South Africa for such purposes. There is no documented evidence of a similar system operating in a junior or high school, more so in a rural area. The AIM system is the first of its kind in South Africa, although there is an existing system in Utah State University, USA. The system in Utah reports agro-environmental measurements but does not allow interaction with measured data (Savage 2014). The research will focus mainly on how the AIM system will improve a community's resilience.

1.3 Nature and scope of study

The area of study is Swayimana High School, Swayimana, 13.5 km from Wartburg, KwaZulu-Natal, South Africa, located at latitude 29°31'8"S, longitude 30°41'40"E and altitude of 875 m. Figure 1.1 is a map indicating the location of the AWS and the school. The study included installing an AWS system, setting up a webpage and installing computer screens for viewing data at Swayimana High School. The suitability of the AIM system as a tool for climate change adaptation education was investigated. The focus was on how it would improve scholars' grasp of environmental concepts and phenomena, assist with their analysis and understanding of statistical weather data and overall appreciation of weather variables and their changes. The AWS system included a six-plate Gill radiation shield and air temperature and relative humidity sensor, raingauge, barometer, wind speed and direction sensor, and a pyranometer. These measure air temperature and relative humidity, rainfall, atmospheric pressure, wind speed and direction, and solar irradiance respectively. Sensors were added for the benefit of smallholder farmers. Leaf wetness, soil water content and soil temperature, as well as grass minimum temperature are all measurements more relevant to farmers.

Figure 3.2 Map indicating exact location of the AWS system at Swayimana High School (Acknowledgement: Google Maps).

1.4 Aims

The overall aim of the study was to determine how the web-based AIM system can enhance the community of Swayimana's resilience to climate variability possibly caused by climate change, in particular high school learners. The study emphasises the use of visual imagery for a better grasp of climate change, its impacts and other complexities. The main aim of the system set-up in Swayimana High School is to study how the system influences the scholars' learning. It is anticipated that the system will also be of benefit to smallholder farmers in the area. What is further expected in time is a dissemination of knowledge (gained from the system) from the scholars to their parents who are farmers in the community. Weather information will be displayed in near real-time on a webpage for scholars and farmers to access. Data are accessed at the web address http://agromet.ukzn.ac.za:5355/Swayimane. From the findings, assumptions can be made about how the web-based system would be received in other rural communities.

1.5 Research question and objectives

An automatic weather station (AWS) with the necessary supporting equipment was installed to collect agro-environmental data. The web-based system consists of an AWS system, connected with antenna, server and computers. A webpage was designed that would display collected data in a simpler way. The intention was to make information easily understood by the layperson.

1.5.1 Research question

How can the web-based system enhance the community of Swayimana's resilience to climate variability caused by climate change?

1.5.2 Specific objectives

- The main objective was to investigate how the web-based system enhances Swayimana High School scholars' learning.
- The second objective was to explore scholars' attitudes towards and perceptions of weather and climate change.
- The third objective was to investigate the response to the web-based system. The system has the potential to add to the community's capacity to adapt and mitigate against the effects of climate variability and change. The intention was to develop the system to be as user-friendly as possible; therefore it is essential to obtain feedback from the scholars using it.

1.6 Outline of dissertation structure

The dissertation employs a traditional format of five chapters, namely Introduction, Literature Review, Materials and Methods, Results, Discussion, and Conclusions and Recommendations. Chapter 1 introduces the research study, extending the title of the dissertation for more understanding. More importantly, it highlights the purpose, aim and specific objectives that will be achieved. Chapter 2 places the study in a global academic context by reviewing other literature and in doing so provides the reasoning behind the study and supports the aims and objectives. It is a detailed expansion of the introduction as it discusses agricultural adaptation strategies at global, national and community level and rural perceptions of climate change. It further focuses on difficulties associated with climate change education, visual literacy and its role. It reviews the reasons for the original development of the AIM web-based system, its applications, its success and briefly describes its setup. Other literature on education systems is reviewed. Finally, meteorological components altered by climate change and impacts are described. Chapter 3 provides a description of Swayimana, demographic and climatic conditions. It also describes the research method and tools used to gather qualitative data. Additionally, it clarifies the process of the set up of the AWS, sensors and software used to create a webpage. Chapter 4 presents results which are then discussed in Chapter 5. Chapter 6 provides an overview, a conclusion of the study and makes recommendations for future research and initiatives. Further, it specifies the limitations and challenges encountered.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Climate change has a severe impact on people's livelihoods because of the influence it has on the availability of their agricultural resources. By affecting agriculture in different ways, climate change has an effect on the quantity, quality and stability of food production (Enete et al. 2011). As much as climate change affects the natural environment where agriculture takes place, economies are also impacted. A decrease in food production in some countries would demand more food imports (Huang et al. 2011). This chapter makes mention of broad strategies that are adopted globally to support climate change adaptation on a community scale. It highlights the importance of adaptation from an economic standpoint and the need for awareness through focusing on the general perceptions of the youth and farmers in rural communities. It focuses on the difficulties of communicating climate change and the use of visual literacy to overcome them. Interventions based on visual literacy for climate change and environmental education are reviewed, although there is not much evidence of many. Finally, this chapter briefly discusses the original development of the AIM system, its success, its various applications and potential, as further justification for this study.

2.2 Global adaptation

Global recommendations for national adaptation strategies were formulated to support the mitigation of climate change. These strategies act as principles that allow for and guide actions against climate change (Below et al. 2010). The development and implementation of good policy is a sustainable strategy (Nelson et al. 2009). This action by governments is essential, as little can be done without a policy first to act as a framework or structure for support of initiatives, programmes and projects (FAO 2007). Nelson et al. (2009) suggests that international development initiatives should aim to improve community resilience by capacity building, improve land management skills and diversification of livelihoods. UNDP (2010) suggests building support systems for continuous and sustainable adaptation that will entail mitigating negative effects, taking advantage of opportunities and managing long-term impacts. To improve understanding of the state of agriculture and the development of appropriate climate change mitigation strategies for land, there needs to be improved global data collection, dissemination and analysis (Nelson et al. 2009). Nelson et al. (2009) further suggests that there should be an increased focus on adaptation within international climate talks and higher investments in agriculture.

2.3 Agricultural adaptation in South Africa

South Africa has responded to international demands brought forth by the Intergovernmental Panel on Climate Change, United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto protocol, for climate change adaptation and greenhouse gas emission reduction. There are five adaptation strategies formulated to be implemented to address climate challenges in the agriculture and forestry sector (DEA 2012; DAFF 2015). South Africa plans to address rural development issues such as lack of employment, food security and unstable livelihoods. The second strategy is about using the existing information provided by risk and vulnerability analysis to develop adaptation scenarios in order to help identify new agricultural opportunities to ease the pressure on existing agricultural potential (Elbehri et al. 2011; DEA 2012; DAFF 2015). The third strategy involves an invigoration of research in water, nutrient and soil conservation techniques and the supporting technologies, climate-tolerant crop-livestock farming systems. This would create and maintain agriculture that produces fewer emissions that aggravate environmental problems and climate change as well as increases agricultural production (DEA 2012; DAFF 2015). The fourth strategy focuses on early warning systems to warn of possible hazardous weather conditions and the resulting prevalence of pests and diseases (Elbehri et al. 2011; DEA 2012; DAFF 2015). This serves as a tool to inform decision-making and improve farm management. Lastly, the government seeks to invest in awareness programmes in rural areas to better understand challenges, respond accordingly and adapt (Elbehri et al. 2011; DEA 2012; DAFF 2015). These strategies are in line with international recommendations (Nelson et al. 2009; DEA 2012; DAFF 2015).

2.3.1 Agricultural adaptation in rural areas

Principles that govern agricultural adaptation nationally are expressed in strategies specifically set to be implemented in rural areas. The first strategy the South African government proposed focuses directly on improving the economic status of rural people. As a way to address socio-economic challenges, government seeks to develop and implement economic and livelihood diversification programmes (DEA 2012; Linkd Environmental Services 2013; DAFF 2015).

As a result of this there would be an increased number of employment and entrepreneurial opportunities, which in turn would increase household income and ensure increased food security. The second strategy is the improvement in the dissemination of low water-use irrigation systems, rainwater harvesting technologies and drought-resistant seed varieties (DEA 2012; Linkd Environmental Services 2013; DAFF 2015). These methods are important for the conservation of natural resources that would otherwise be depleted and therefore promote the development of climate-smart agriculture (DEA 2012; DAFF 2015).

Education remains the most critical strategy because application of the other strategies in rural communities is dependent on it. The distribution of technologies by government is ineffective unless people know how, why and when to use them, and how to maximise their use for the best outcome (DEA 2012; Linkd Environmental Services 2013; DAFF 2015). The last three of government's strategies all complement and emphasise education and awareness. Government plans to prioritise empowering communities, especially women, who are usually primary producers, in the process of development and implementation of adaptation strategies (DEA 2012; DAFF 2015). It also plans to identify the most vulnerable rural population to build resilience by providing safety nets to ensure better disaster management. The last of these strategies includes enhancing their knowledge on sustainably exploiting ecosystem services (Linkd Environmental Services 2013). This provides education to smallholder farmers on the risks climate change poses, the conservation practices and their buffering potential. This strategy recognises and places emphasis on the potency of indigenous knowledge and local adaptive responses (DEA 2012; Linkd Environmental Services 2013; DAFF 2015).

2.4 Rural perceptions of climate change

Perceptions greatly influence how smallholder farmers in rural communities respond to climate change effects. Perception level is associated with smallholder famers' ability to minimise risks and maximize opportunity. It is associated with climate variability and enhances their behavioural responses which affect possible adaptation inputs, processes and results. Further, it affects willingness to participate in conservation practices introduced by initiatives and implement recommended strategies that are unfamiliar (Enete et al. 2011). No adaptation or applying imprecise adaptation practices due to a poor perception can result, thus perpetuating the adverse effects of climate change (Debela et al. 2015). Several studies show that farmers notice change in climatic conditions, however their perceptions on the direction of agricultural production in response to these changes varied (Enete et al. 2011; Kalungu et al. 2013; Debela et al. 2015). Some thought that yield was decreasing while others noticed an increase, and others did not appear to view climate change as a threatening phenomenon with long-term implications (Debela et al. 2015; Dlamini 2015). Age, the number of years they had been farming, livestock holding, education level and access to information are among the factors that shape their perception (Debela et al. 2015).

2.5 Challenges to agricultural adaptation for smallholder farmers

Climate change adaptation has been associated with a number of problems. These constraints are a direct or an indirect consequence of poverty at national as well as household level (Deressa et al. 2009). One problem is a poor distribution of improved seed varieties which have a greater chance of surviving extreme conditions and timely weather forecasts (Enete et al. 2011). There is a lack of financial resources and natural resources such as water for irrigation and land for strategies that involve expansion. The shortage of labour to implement strategies and a lack of information also play a part in decreasing adaptive capacity. Age, access to information through extension services and other sources, education and farm size, are included in the factors that determine preparedness to adopt strategies (Enete et al. 2011).

2.6 Youth involvement

Very few studies integrate youth, climate change and agricultural adaptation, although it has been noted that youth could be instrumental in climate change adaptation (Akinnifesi 2013; Nwobodo and Agwu 2015). Akinnifesi (2013) found that youth involvement has the potential to rid Africa of its food security challenges. Aphunu and Atoma (2010) stated that the youth is considered to be the more energetic group and their involvement is essential. The lack of research in this area can possibly be attributed to the youths' inadequate involvement in agriculture. Akinnifesi (2013) found that agriculture is not a sector that is popular with Africa's youth because of the perception that it is for the least educated people, and for its association with tiresome activities and drudgery, which results in low income. The labour-demanding nature of agriculture and the long time it takes for investments to yield benefits enhances this perception. Other factors that decrease the attractiveness of agriculture are misconceptions. These factors, coupled with the challenges of financial risks, land tenure issues, limits to financial capital and access to markets all decrease the degree of interest for young people

(Akinnifesi 2013; Mashala 2016). The youth in rural areas are not excluded from this type of mind-set although their involvement is even more pivotal.

2.6.1 Youth perceptions of climate change

Several studies have been conducted to investigate the level of understanding that young people in rural areas have about climate change. Youth were aware of the extended season and extremity of a certain condition associated with that season (Nguyen-Quang et al. undated; UNPF 2009). Nguyen-Quang et al. (undated) divided youth into two groups in their study based on their age: 19-25 years and 15-18 years. The older ones generally knew more about climate change while the younger ones were focused on their scholastic education. The 15-18 years group felt climate change and its impacts could not be avoided and the form of resilience was migration to urban areas and finding employment. Nwobodo and Agwu (2015) found that youth did not fully grasp the fundamental science, its implications or the most appropriate responses to it therefore, effective education is needed.

2.7 Difficulties with climate change communication

Monroe et al. (2015) found four challenges in climate change communication to the layperson. One of the main reasons is the very complex nature of the subject. It is a natural process primarily accelerated by greenhouse gases that are trapped in the Earth's atmosphere. These gases are emitted through anthropogenic activities (Mavi and Tupper 2004). Greenhouse gases are unseen and do not have direct and immediate effects on humans or the environment. Further, their release by an individual activity at a given time is trivial, so the manifestation of their effects is due to accumulation over time. Climate change is gradual, continuous with known and hidden distant impacts (Moser 2010). Its causes and effects are difficult to comprehend and requires knowledge of long-term trends. It is also very unpredictable since its physical effects are highly dependent on geographical location. Further, there are still many knowledge gaps that researchers are attempting to fill by exploring relationships between climate variables within the climate system. Consequently, there is still much uncertainty because the subject is not entirely understood, even by experts (Moser 2010; Monroe et al. 2015).

Monroe et al. (2015) identified more psychologically focused difficulties to communicating climate change, as they are associated with how people receive and perceive information. Experience often acts as a catalyst to learning; hence it is easier for people to receive information if they have noticed significant changes in climate. People are less likely to learn about climate change and as a result begin behavioural changes in response to it if they have not experienced or recognised significant effects (Monroe et al. 2015). Another challenge is in our information-rich environment, information competes for our attention. We tend to be very selective in our learning and are less likely to accept information that conflicts with our beliefs. The last difficulty is described as the Identity Protective Cognitive Theory, which suggests that the reception of information is based on cultural identity. We are more likely to listen to and trust people with whom we can identify (Monroe et al. 2015).

Wibeck (2013) suggests four types of solutions that could overcome climate change communication to improve the layperson involvement. They are namely, the content of climate change, visualisation, framing, and audience segmentation and complement each other. The content of climate change focuses on communicating climate change in a way that empowers the audience to participate in mitigation. Messages of climate change often communicate destruction and leave the layperson with a very negative perspective and feelings of helplessness (Carr 2015; Anderson 2017). Communication should present it as an issue that can be mitigated or adapted to instead of a catastrophic environmental problem (Wibeck 2013). Visualisations involve communicating climate change through images to overcome challenges that arise because of its invisible nature. Pictures capturing individuals involved in practical strategies of adaptation and mitigation should be used to create a sense of agency and empowerment. Audience segmentation divides the heterogeneous population, grouping it according to their similar characteristics. Grouping can be informed by climate change risk perceptions, values, beliefs, and media use and policy preferences (Wibeck 2013). Framing in this sense refers to how climate change is communicated to target groups and complements audience segmentation. It is recommended that it be reframed to resonate with the concerns of the target groups to encourage public involvement. Instead of an environmental issue, it can be reframed as a religious or moral issue, a public health problem, a security or economic issue. Reframing it as a health issue has brought about the most public response in the United States of America. Understanding the audiences' opinions towards a certain local resource or an issue is essential for environmental education (Wibeck 2013).

2.7.1 The role of language in learning

There are undeniable links between language and learning, because of their connections with thought and meaning. It influences people's understanding of science and their surrounding environment. Without having a proper grasp of the language used for science communication there cannot be an appreciation for what is being taught. Science is usually taught in English because scientific (agro-environmental) concepts and terms are better expressed. When the recipient (scholar) is not an English speaker it places them at a disadvantage (Oyoo 2015). Savage (2014) found that university scholars preferred to be taught in English to their home languages since some terms that describe important aspects of climate and the environment are absent in South African local/indigenous languages. Phrases such as "greenhouse gases" and "ozone layer" are among those that do not exist in theses languages. IsiZulu in particular (the most dominant language in KwaZulu-Natal), does not make a distinction between "weather" and "climate". These are phrases that are a fundamental part of understanding climate change as an occurring global phenomenon and as a science. Overcoming this problem would need academics and linguistics to form glossaries in local languages of terms corresponding to the technical terms in natural science disciplines (Savage 2014).

2.8 Visual literacy

Visualisation in climate change education has the ability to overcome communication challenges as it makes the topic more concrete and tangible (Wibeck 2008). Teaching technical and scientific content using graphic images was discovered many years ago to be more effective than words. Under the logic of "a picture paints a thousand words" and "seeing is believing", images have been used to communicate the state of the world and its systems (Lowe 2000; Wibeck 2013). Seen imagery is generally easier to cognitively retain. Studies show that likelihood to remember something is much greater if the information is presented visually. An estimated 65 % of scholars are visual learners, as human brains process visual information 60000 times faster compared to written information (Bellato 2013). Visual symbols are easy to recognise which translates to a quicker and more in depth understanding of ideas presented. It also minimises the need for words, thereby decreasing the role of language, therefore one learns and understands despite one's grasp (proficiency) of the language of communication (Plotnick 1997).

A study conducted by Ballantyne et al. (2015) found that visualisation can help bring climate change to a point where it is not an abstract concept but a reality. The ICT visualisation method used in this study was a short film called “A warmer world”. The film is a 30-minute dome theater production with the youth as its target audience. It introduces the topic and delves into the causes and consequences, and highlights the need for adaptation and mitigation in all spheres. It focuses on the anthropogenic factors that accelerate climate change, namely greenhouse gases and population growth. Different climate scenarios (A2, A1B and B2) are used to illustrate the increasing global temperatures from 1960 to 2100. Furthermore, the film presents mitigation options that individuals can adopt to reduce impacts. The target sample for the study, high school scholars, felt that the movie helped them better understand aspects of climate change. However, it would have benefitted the scholars more had there been an interactive element (component) added to the learning session, therefore highlighting the shortfall to the movie being the only teaching source (Ballantyne et al. 2015).

2.8.1 Information and communication technologies (ICT) visualisation methods

Rosier and Dyer (2010) provided an account of different visualisation methods, highlighting their application and limitations. Photographs are easier to comprehend as they are a direct representation of a present reality and are therefore easier to receive (accept as truth). Hypermedia represents various communication methods combined namely, videos, maps, animation, text, graphics sounds and statistical data. It allows for a presentation of a combination (mixing) of different information, namely economic, environmental, and social (Munroe 2012).

An example of an ICT system that makes use of hypermedia is a web-based agro-environmental system at Utah State University that began operation in 2011. The system measures and reports meteorological and agro-environmental elements such as dew point and humidity, subsurface temperature, and CO_2 concentration. It presents two-year graphs of data along with a description of the element being presented and other relevant additional information. Its webpage address is http://weather.usu.edu/htm/publicity. This system does not allow for much interaction with the data it presents as the data cannot be downloaded by scholars (Savage 2014). This system however, contains predominantly statistical visuals and lacks graphics, therefore is difficult for non-expert or the layperson to use. To determine the effectiveness of various visualisation methods, Senaratne et al. (2013) conducted a web-based survey to assess participants' performance in each of these methods. The participants responded more to the highly visual methods compared to the more statistical methods.

2.9 The Agrometeorology Instrumentation Mast (AIM) system

The AIM system is a web-based system located at the University of KwaZulu-Natal, Pietermaritzburg campus. The system consists of five masts at the Agriculture Campus roughly constructed at coordinates latitude 29°37'40"S longitude 30°24'9"E and altitude 671.3 m. It displays agrometeorological data collected at the five masts at webpage http://agromet.ukzn.ac.za:5355. It is a visual tool that displays near real-time weather data and was originally designed to aid teaching, learning and research. Topics that are covered include climate change and connection to CO_2 and El Niño southern oscillation.

2.9.1 Specifications of the AIM system

Mast 1 is an AWS system that records the basic measurements, namely, air temperature, atmospheric pressure, relative humidity, wind speed and direction, solar irradiance and rainfall. Additional measurements are air temperature profile, grass minimum temperature, net radiation components, soil water content, soil temperature profile, and leaf wetness. Mast 2 acts as a backup for the main mast, therefore it mimics its function. The measurement of the heat index is the only unique feature the station accommodates. Popularly known as human comfort, it describes a perceived temperature experienced when air temperature and relative humidity are greater than 26.7 ^{o}C and 40 % respectively. Mast 3, the temperature station, consists of air temperature and relative humidity sensors of various types. A radiation station on a roofed building is dedicated to measuring solar and diffuse radiation as well as estimating sunshine duration. The microclimate in a polycarbonate greenhouse is monitored by temperature and relative humidity sensors. Since the purpose of a greenhouse is to create the best microclimate for optimal plant growth, measurements must be taken to help maintain these conditions (Savage 2014). Figure 2.1 is an aerial map indicating the location of the masts and the ICFR nursery in addition. The ICFR (Institute for Commercial Forestry Research) nursery housed a microclimate measurement and irrigation control system which began operation in December 2011 and ended in February 2013.

Figure 2.1 The AIM system indicating two masts, (21 m apart) the horizontal-mast air temperature station, the ICFR nursery, radiation station and polycarbonate greenhouse (acknowledgement: Savage 2014).

2.9.2 Applications of the AIM system

Basic measurements that are recorded include air temperature and relative humidity, rainfall, solar irradiance, wind speed and direction. Air temperature at heights 0.1, 1, 2, 3, 4, 5, 6, 7 and 8 m, grass-surface temperature, and soil-surface and soil (at different depths) temperature are measured. Heat index and wind chill are measured as they also directly influence human comfort. Energy balance, CO_2 concentration, wind velocity and wind rose are measured. Leaf wetness, grass reference evaporation (short grass and tall crop), soil water and salinity are among the other measurements (Savage 2014).

2.9.2.1 The AIM website

The AIM website comprises nine screens, namely, Weather, Greenhouse microclimate, Human comfort, Fire, Berg winds, Radiation balance, Floods, Wind velocity and Air temperature profile. These mostly focus on different weather conditions and highlight different relationships or interactions between elements that cause them. For example, the fire screen displays the Fire Danger Index (FDI), which calculates the likelihood of fire occurrence through interaction between air temperature and relative humidity and wind speed. Berg winds occur when certain air temperature, solar irradiance, relative humidity, wind speed and direction and air pressure conditions are met. Measurements relevant to frost are namely, air temperature, air temperature profile gradient, wind speed, grass minimum and the grass-surface temperatures. The system is used for teaching and learning and research by undergraduate and postgraduate scholars of various disciplines in the College of Agriculture, Engineering and Environmental Science.

2.9.3 Findings from the AIM system

Scholars who utilised the system from years 2011 to 2013 indicated greater appreciation for the ranges in weather variables and their interactions with agricultural elements. The website contained images that demonstrated weather conditions and their ranges. An example of an image that expresses low air temperature measurement below a certain degree, would be an image of a shivering person dressed for a cold day. A high temperature measurement would be expressed by a person shading herself from the sun with visibly-applied sunscreen lotion. This representation of data using pictures meant that agro-environmental components measured and concepts were easily understood and appreciated (Savage 2014).

Scholars were able to download data from the website and display it in an Excel spreadsheet, draw temporal, regression and other types of graphs. This skill produced the ability to analyse raw and manipulate statistical, agro-environmental data. Instructions on how to download data and the definition of agro-environmental terms are incorporated in the website. Scholars also indicated a deeper understanding of agro-environmental concepts that otherwise would have been difficult for them to grasp. This understanding, however, was attributed to visualisation of data more than written definition of terms (Savage 2014).

Overall, scholars were more aware of global climate change since they were exposed to visualised climate and weather data. The system provided contemporary and past data for atmospheric CO_2 concentrations, which described its increase. Trends for global air temperature anomaly, in both the northern and southern hemispheres, are also included. The scholars' understanding was dependent on their existing visual literacy skills, but their skills were also improved after exposure to the web-based system.

2.10 Meteorological components and their impacts on agriculture

Climate essentially describes a combination of meteorological components and their interactions, over a long period of time. These are namely solar radiation, air temperature, rainfall, relative humidity, wind speed and direction. With the exception of rainfall and wind direction these components comprise factors that influence the microclimate of plants and animals (Goosse et al. 2010; DAFF 2015). Their shifts and changes cause adverse effects on the natural elements that support agriculture. Climate change is projected to have both negative and positive effects on agriculture but the overall (net) result is likely to be negative. It is projected that there will be improved crop growth in some areas but mostly climate change impacts will reduce production (Antle 2008; Gepts et al. 2010).

2.10.1 Solar radiation

Solar radiation, like wind speed and direction, is independent of climate change, and instead drives it. The sun provides the earth with energy that influences its climate system. Its variations have been linked to natural climate change (Shindell 1999). Solar variability, interactions with earth elements and the systems that determine the earth's response aids in understanding the influence of solar radiation on climate. Studies show that the total solar irradiance throughout history has been changing continuously, supporting evidence of climate conditions at different time periods. Variations in total solar irradiance are associated with 11-year solar cycles and the range between the sunspot minimum and sunspot maximum (Gray et al. 2010). Direct effects of solar variations have predominant influence on the thermosphere. Climate changes on the earth's surface in response to these variations are produced by the progressive heating of the mesosphere and stratosphere (Shindell 1999).

Climate change is often associated with global warming and the greenhouse effect. Greenhouse emissions are gases that divert the pathway of infrared radiation (Ming et al. 2014). Decreased net infrared irradiance due to increased greenhouse emissions results in a gradual warming (Karl and Trenberth 2003; Ming et al. 2014). Solar radiation influences the air temperature and consequently, rainfall. The heating of the lower atmosphere results in a higher rate of evaporation and a higher atmospheric water vapour accumulation, resulting in higher risk for rainfall events (Karl and Trenberth 2003). Figure 2.2 shows global trends of [CO_2] presence, solar radiation and the air temperature anomaly from 1880 to 2000.

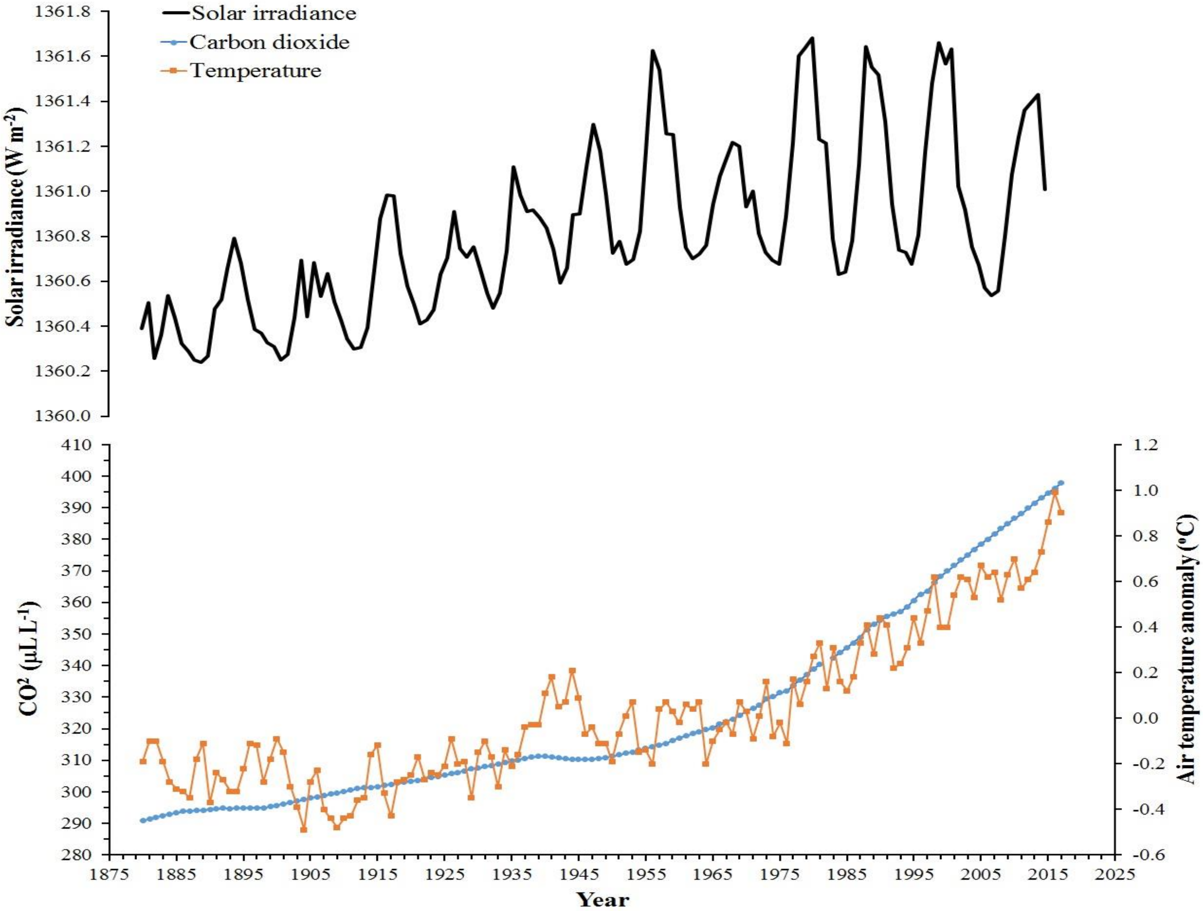


Figure 4.2 Temporal graph representing solar irradiance, global (land and ocean) temperature anomaly and concentration in greenhouse gas carbon dioxide (Courtesy of NASA2017; SORCE 2017).

The amount of solar irradiance received is dependent on time of day, season and cloud cover. Plant production is dependent on the direct and diffuse radiation they intercept. An increase in solar irradiance theoretically increases plant yield as radiation is essential for photosynthesis (Campillo et al. 2012). Solar radiation and duration also have implications on plant disease occurrence and severity. Plant pathogen responses to radiation vary depending on type of plant and pathogen. Research suggests that ultraviolet radiation triggers the production of phytoalexins which are protective pigments in plant tissue (Gautam et al. 2013). Therefore, the general response to solar radiation is positive as it contributes to a decreased risk of disease development (Gautam et al. 2013).

2.10.1.1 The influence of carbon dioxide

Increase in carbon dioxide concentration is projected by climate change models (Antle 2008). Carbon dioxide along with solar radiation, water vapour and chlorophyll is an essential element for the process of photosynthesis. The increase in carbon dioxide concentration would result in an increase in plant growth because there is more carbon dioxide available for photosynthesis (Taub 2010). An increase in the gas concentration is said to have a positive effect on the growth of staple crops such as maize (Antle 2008; Enete et al. 2011). Climate change also changes the distribution of wild crop species that are increasingly recognised as vital for food security (Gepts et al. 2010; Enete et al. 2011).

Research suggests that carbon dioxide levels affect the incidence of pathogens by influencing plant biomass. There is an increase in the likelihood of pathogens because of the composition of the plant (Gautam et al. 2013). Carbohydrates in plant tissue encourage development of fungi such as rust. Longer leaf wetness duration due to higher plant density also suggests an increase in pathogen occurrence risk (Gautam et al. 2013). Therefore, pathogens promoted by elevated carbon dioxide levels are a consequence of alteration in plant physiology and morphology (Paterson and Lima 2010).

2.10.2 The influence of air temperature

One positive effect of climate change in crop production is the result of the general global temperature increase. There would be an increase in yield potential at higher altitudes and at the poles because plant species generally thrive under warmer conditions. Warmer temperatures in other areas provide crops with a shorter time for growth, therefore allowing for the possibility for earlier planting and harvesting, meaning there can be two harvests of the same crop in one growing season. In other words, a farmer is able to double the production of a certain crop (Enete et al. 2011). Temperature counts as one of the factors that accelerate humus formation. Warmer temperatures speed up processes in the soil and aid in the breakdown of organic matter. This benefits crop quality and yield as there are more nutrients available for uptake (Enete et al. 2011).

Higher air temperatures offer benefits for the process of nitrogen fixation which is important for soil fertility and plant root development. Nitrogen is produced by a symbiotic relationship between legume roots and bacteria (Rhizobium and Actinomycetes) (Simms and Taylor 2002). Soil temperatures influence bacteria growth rate and activity (Pietikäinen et al. 2005). Optimum temperatures for bacterial activity were between 25- 30 ^{o}C. A higher rate of biological nitrogen fixation occurs with warmer soil temperatures. Plant-usable nitrogen is also produced by lightning flashes and transported to the ground by rain. Research shows a positive correlation between increased air temperature and thunderstorms (Price 2009). Therefore, a higher incidence of lightning nitrogen fixation occurs.

Higher temperatures, beyond the optimal level of a crop will cause their physiological destruction (Enete et al. 2011). A higher temperature can also act as a catalyst for increased natural processes such as evaporation and transpiration. Due to the increased rate of evaporation over land surfaces the soil becomes drier, leading to cracking and formation of a hard crust in a process called crusting, in extreme cases. A soil crust is a top layer which has high density, shear strength and lower intrinsic permeability compared to soil underneath it. Drier and crusted soils result in decreased potential of infiltration, seedling emergence and a higher surface runoff, which further increases its vulnerability to soil erosion (Zejun et al. 2002; Pagliai 2007). Higher rate of transpiration coupled with less soil water content results in more wilting. Heat stressed plants suffer from distorted physiological development and maturation, therefore influencing yield in a negative way (Enete et al. 2011).

2.10.3 The influence of rainfall

Rainfall is an important meteorological component and an undeniable influencing factor for crop production and agriculture as a whole (Gornall 2010; Kabir and Golder 2017). Higher rainfall presents both advantages and disadvantages depending on the specific region of the increase. An estimated 80 % of global agriculture is rain-fed which means it is highly dependent on the climate (Mavi and Tupper 2004; Gornall 2010). Further, more rainfall fills water resources and replenishes the ground water supply, which can act as water reserves during drier periods (Mavi and Tupper 2004).

Higher rainfall intensity means accelerated soil erosion in steep areas (when there is sparse or no soil cover); therefore, the soil suffers a reduced capacity to produce crops because of the nutrient-rich sphere that has been washed off (Hansen and Hellerstein 2004). Soil upon deposition can cause damage to existing crops in that area. Agriculture is affected indirectly due to the further implications of soil erosion. Soil erosion affects availability of water. The eroded soil is washed into rivers and water sources, thereby decreasing the capacity for water storage resulting in a lower volume of water available for agricultural use (Hansen and Hellerstein 2004). Higher temperatures and lower rainfall consequently lead to increased land drying. This further leads to more dry spells, and droughts in some regions imply a spread in desert-like conditions. The potential for production is decreased in this case as well (Karl and Trenberth 2003; Enete et al. 2011).

Flooding or frequent high intensity rainfall events cause soil compaction, sealing and crusting. The nature of soil-water interaction allows for these forms of soil phenomena to occur. A rainfall event results in either one or a combination of these processes: compaction, disintegration, detachment, entrainment and deposition of soil (Zejun et al. 2002). The formation of soil crusts relies on several factors, namely: conditions of the soil, rainfall intensity, gradient of slope and concentration of electrolytes in the soil. Crusting forms by disintegration and compaction of soil particles because of the impact of individual raindrops (Zejun et al. 2002). These types of soil degradation can also be a result of an interaction of climate change characteristics. FAO (2007) stated that the changes in climatic variables will negatively affect up to 11 % of arable land in the developing world as a whole.

Climate change creates ideal conditions for pathogens to thrive, allowing diseases to flourish. Increased temperature and rainfall, implying higher relative humidity and leaf wetness, are the conditions responsible for a 10-16 % loss in global harvest (Gautam et al. 2013). The most common pathogens that thrive under the mentioned conditions are fungi, nematodes, bacteria and algae. The interference by pests also increases the likelihood of developing diseases. Insect and bird damage has a positive correlation for mycotoxin incidence. Mycotoxins are poisonous molecular compounds caused by fungi (Paterson and Lima 2010).

2.10.4 Important topics within agriculture

2.10.4.1 Livestock

The effects of climate change on livestock are not studied as intensely as compared to those on important crop and plant species. It is a rather neglected area of research. However, livestock rearing makes up a large proportion of agriculture, and its importance is undeniable. Similar to crops, livestock suffer from heat stress as a result of high temperatures above their tolerance zone. The five cardinal levels of temperature for organisms are: zone of intolerance for minimum temperature, critical minimum zone, range of optimum, critical maximum zone and zone of intolerance (Savage 2012). The exact temperature at which these cardinal levels rest depends on the type of animal. The tolerance curve of organisms is shown (Figure 2.3). Heat stress is known to have an influence on milk and egg production in cattle and chickens, respectively. Conception rates are also negatively influenced by heat stress in goats, chickens, cattle and pigs (Munzhedzi 2013). Floods, droughts and dry spells have direct impacts on livestock as they lead to retardation of growth and even death. The proper development of animals is hindered because of reduced feeding time due to these extreme weather events (IFAD 2009).

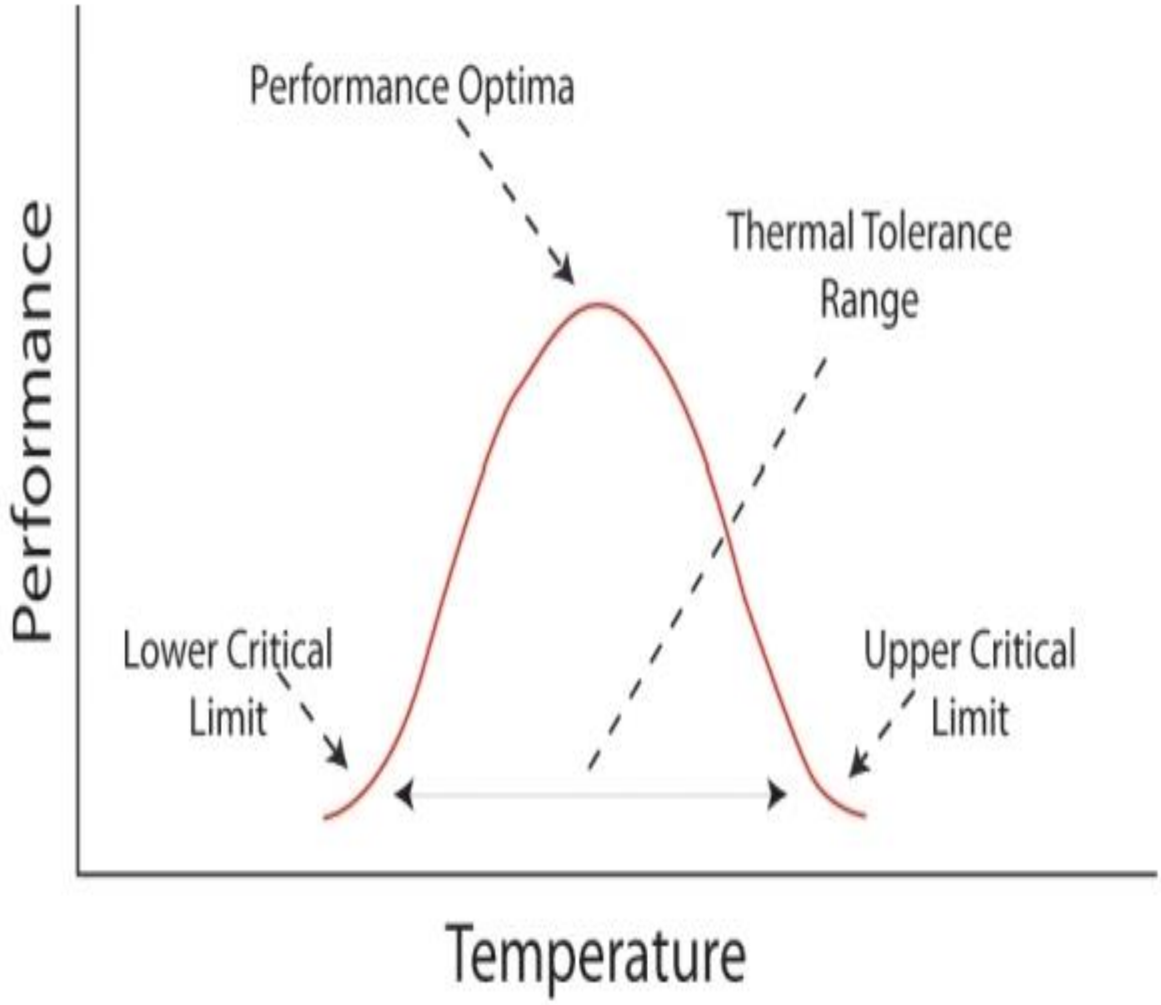


Figure 2.3 Graph representing organism performance vs temperature. (acknowledgement: Miller and Stillman 2012).

Climate change is detrimental to animal health and well-being because of the conditions that arise (Taqi et al. 2013). The environmental conditions projected in some areas are conducive to growth of fungi and microorganisms. Therefore, livestock is more prone to diseases. The wet and warm conditions are favourable for pests to thrive. Climate change affects the availability of forage and fodder. For example, forage for cattle in drier areas will decrease. Not only is it the availability of fodder that will decrease but also its quality. Fodder would likely be lacking in essential nutrients or be diseased. Further, increased prevalence of mycotoxins in a crop that is used as fodder, would result in decreased quality and would in turn transfer the mycotoxins to the livestock (Paterson and Lima 2010). Less quality feed for livestock has obvious effects on growth and overall production (IFAD 2009).

2.10.4.2 Human comfort

When examining climate change effects on agriculture, researchers often neglect the effects on farm labourers. For human comfort levels to be higher than air temperature, air temperature and relative humidity need to be higher than 26.7 ^{o}C and 40 %, respectively. By affecting heat index, high temperature and humidity levels have implications on crop productivity (Munzhedzi 2013). Human comfort might not be taken into consideration in the commercial farm context because human labour is replaced with machines, but it is worth considering in a small-scale setting. Due to climate change, the world will lose about 30 % of food production while 16 % of GDP attracted by agriculture in 65 countries is retarded (Enete et al. 2014).

2.11 Agriculture influences climate change

The earth has seen changes in climate ever since the beginning of its existence. Evidence reveals that throughout history, there have been alternating periods of extremely cold and extremely hot weather (Zachos et al. 2001). It is a pattern that the earth and its inhabitants cannot escape. Over time it has been confirmed that climate change is indeed a natural process, however humans have accelerated it through their various activities (Johnson 2011). According to Enete et al. (2011) agriculture contributes over 20 % of greenhouse emissions and accelerates global warming. Agriculture results in the release of two potent greenhouse gases, namely, nitrous oxide and methane (World Bank 2008). These gases are 300 (methane) and 25 (nitrous oxide) times more potent than carbon dioxide as a greenhouse gas (EPA 2015). The activities most associated with their release include application of chemical fertilizers, land clearing and deforestation as well as livestock rearing. More specifically, the use of nitrogenous fertilizers and livestock manure, burning of biomass, animal waste treatment, rice paddies and fermentation by ruminants contributes to the release of these gases (Enete et al. 2011). The release of carbon dioxide is not exempt; soil acts as storage for carbon dioxide. When farmers till the soil during cultivation and land preparation, they cause its emission (ESA 2000). Agriculture also contributes to climate change indirectly, by using a large amount of energy to produce chemical fertilizers and pesticides. The use of soy-based animal feeds requires the burning of fuel which consequently releases carbon monoxide.

2.12 Summary

This chapter finds links between global recommended adaptation strategies to national and communal adaptation. It confirms the need for the two particular climate change adaptation strategies which are education and dissemination of technologies and tools. One particular tool highlighted is the AIM system which was developed at UKZN for teaching, learning and research. Smallholder farmers and youth have been identified as significant in driving climate change mitigation and adaptation in rural communities. Initiatives and programmes that focus on their awareness to climate change and its strategies for mitigation and adaptation are therefore very important. Their perceptions and challenges are documented, further reinforcing the need for the type of adaptation mentioned. Climate change, its important meteorological components and agricultural impacts are also discussed.

CHAPTER 3: MATERIALS AND METHODS

3.1 Introduction

This chapter clarifies the methodology employed for installation of the AIM system in Swayimana and the qualitative data collection in this study. A bioclimatic and demographic description of the study area will be given. Data are obtained from previous research studies conducted on the area. There are not many documented descriptions on Swayimana in isolation, therefore there is inadequate information on the area. Prevalent climatic conditions, agro-ecological zones, land cover, economic status as well as other demographic descriptions will be presented. Specifications of the AWS system and details of webpage set-up are provided. Lastly the methodology and tools used to assess the effectiveness of the AIM system are highlighted. Specifically, the research methodology section will focus on the design of the questionnaire that was administered to fulfil the specific objectives of the study.

3.2 The description of the study area

Swayimana is a rural community in the UMshwathi Local Municipality that falls under the greater uMgungundlovu District Municipality. It is located 18.5 km from the small town of Wartburg, north east of Pietermaritzburg. It covers about 36.35 km^2 of the 1811 km^2 of UMshwathi Municipality, has 2301 homesteads and more than 11486 residents (Frith 2013, as cited by Khumalo 2014). It is subject to the traditional authority of Nkosiyezwe Gcumisa, which is evident in the customary practice in the community (Khumalo 2014).

3.2.1 Bioclimatic conditions

The climatic zone for the Swayimana area is subtropical coastal, and is classified as the Savanna biome (Rutherford 2006; Conradie 2012). More specifically, Swayimana falls under the bioclimatic region 3 which is known as the mist-belt (Matungul 2000). The characteristics of these three zones overlap and describe similar conditions. The high agricultural potential is evident by the average annual rainfall received, cool temperatures, deep and fertile soils. Swayimana has a gentle topography as it lies between the elevation 800 and 1000 m and has a good supply of water from rainfall received **(**Matungul 2002; Khumalo 2014**)**. The average annual air temperatures are between 16 and 18 °C while precipitation exceeds 1000 mm **(**Matungul 2002; Khumalo 2014**)**. Research shows that the soils found in the area are amongst the richest in the country. These are deep, loamy soils that possess characteristics of melanic soils (Fey 2010; Khumalo 2014). According to Jackson 2008 the dark colour on soil indicates high organic matter which implies high fertility. The mist-belt is also associated with climate hazards such as Berg winds, occasional dry spells, excessive cloudiness and hail in spring and summer. Winter is characterised by slight to severe frost occurrences (le Roux undated). Land use is predominantly (subsistence and commercial) agriculture, and cultivation of soils for perennial and annual crop production. Agriculture is focused on crop growth (taro, sweet potatoes, potatoes, cabbage, beans, maize and spinach) and sugarcane planting, more than livestock rearing (Matungul 2000; Khumalo 2014). Figure 3.1 shows the climatic regions of South Africa where Swayimana lies in the temperate interior climate zone.

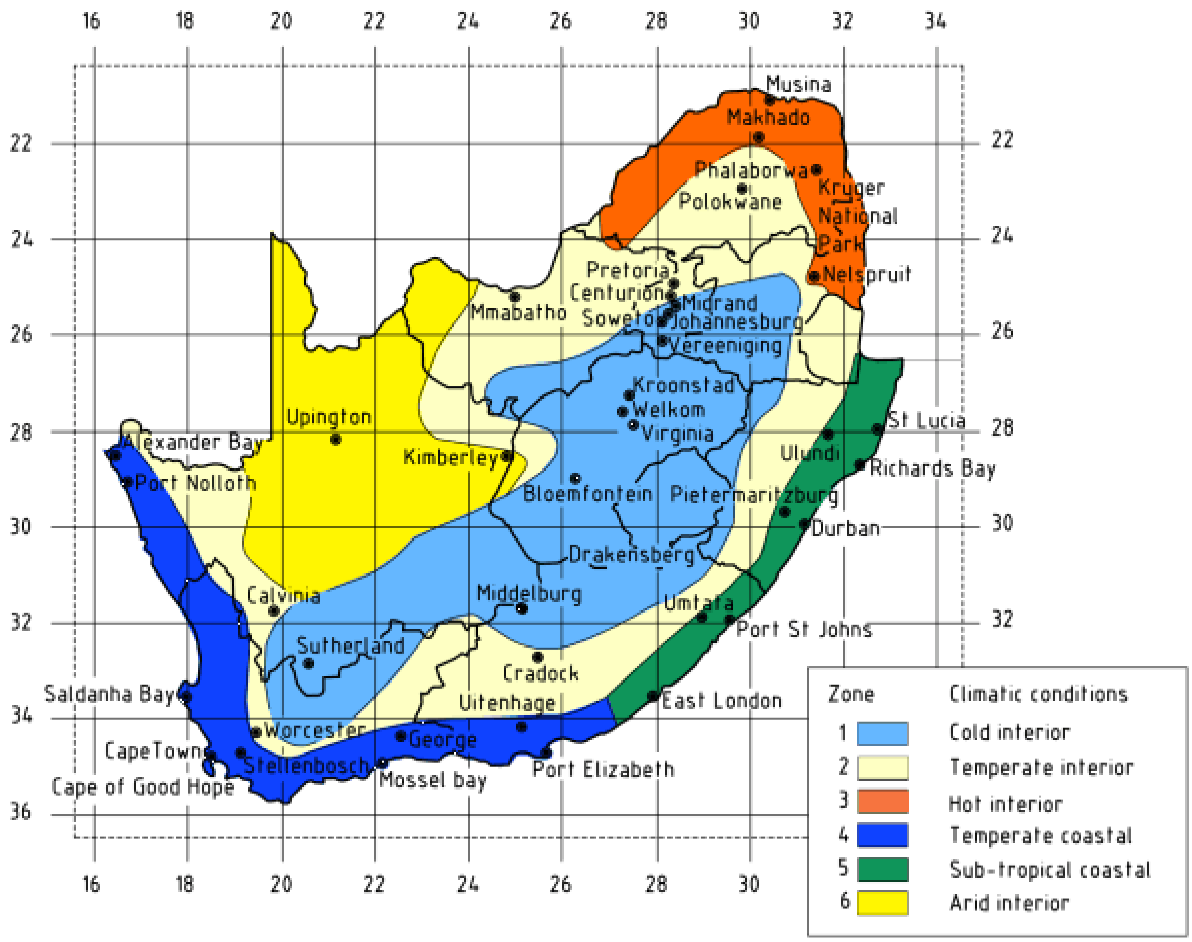


Figure 3.1 Map indicating the different climatic zones of South Africa (Conradie 2012).

3.2.2 Demographic description

The total population of UMshwathi is 113054 of which 46.9 % are male and 53.1 % are females of which 49 % are under the age of 19 years (Khumalo 2014; UMngeni Resilience Project 2014). Education levels of household heads are generally low, with an average of six years of formal schooling. Since land in Swayimana is used mainly for agriculture (subsistence farming), it produces a large fraction of income in households. Mantungul (2002) found that the majority of households received between R1000 and R2500 monthly from other sources of income. These include social grants, employment earnings, remittances and income from other business activities. The area is characterised by poverty, a consequence of a high unemployment rate and a high HIV/Aids prevalence rate (Khumalo 2014).

3.3 Automatic weather station system set-up

The automatic weather station (AWS) system was mounted, using the WMO (world meteorology organisation) standards, on a cleared, grassy and flat surface away from buildings, trees or tall weeds. The mast was attached to a tripod secured to the ground. The enclosure, which contained the CR3000 datalogger, power regulator, a modem, a barometer and a battery, was mounted at a height of 1.5 m. The wind speed and direction sensor was mounted with the wiring box pointing true south and the wind vane true north. To test whether the wind direction and speed sensor was in the correct position, it was connected to the datalogger to ascertain if it reads 0^o or 360^o. The solar irradiance sensor was then mounted on the plate facing the sun in order to record unobstructed measurements. The air temperature and relative humidity sensor was inserted into the radiation shield and stands at a height of 2.5 m. The minimum sensor height should be 2 m for measuring air temperature, hence the sensor stands at a suitable height (WMO 2008). The raingauge, secured to a vertical pipe, was placed less than a metre away from the mast to measure rainfall. The leaf wetness sensor was attached with cable ties to the tripod leg at a height of 150 mm. This low height was chosen to ensure that the sensor fully conforms to the state of a crop leaf, which is generally low-lying. Soil sensors were driven into the ground, horizontally to different depths. Finally, the solar panel was mounted at 1 m to face north at midday in order to receive the maximum amount of solar radiation (WMO 2008). The sensors were wired into the datalogger with the aid of a wiring diagram. Figure 3.2 is an image of the completely installed AWS with labelled parts.

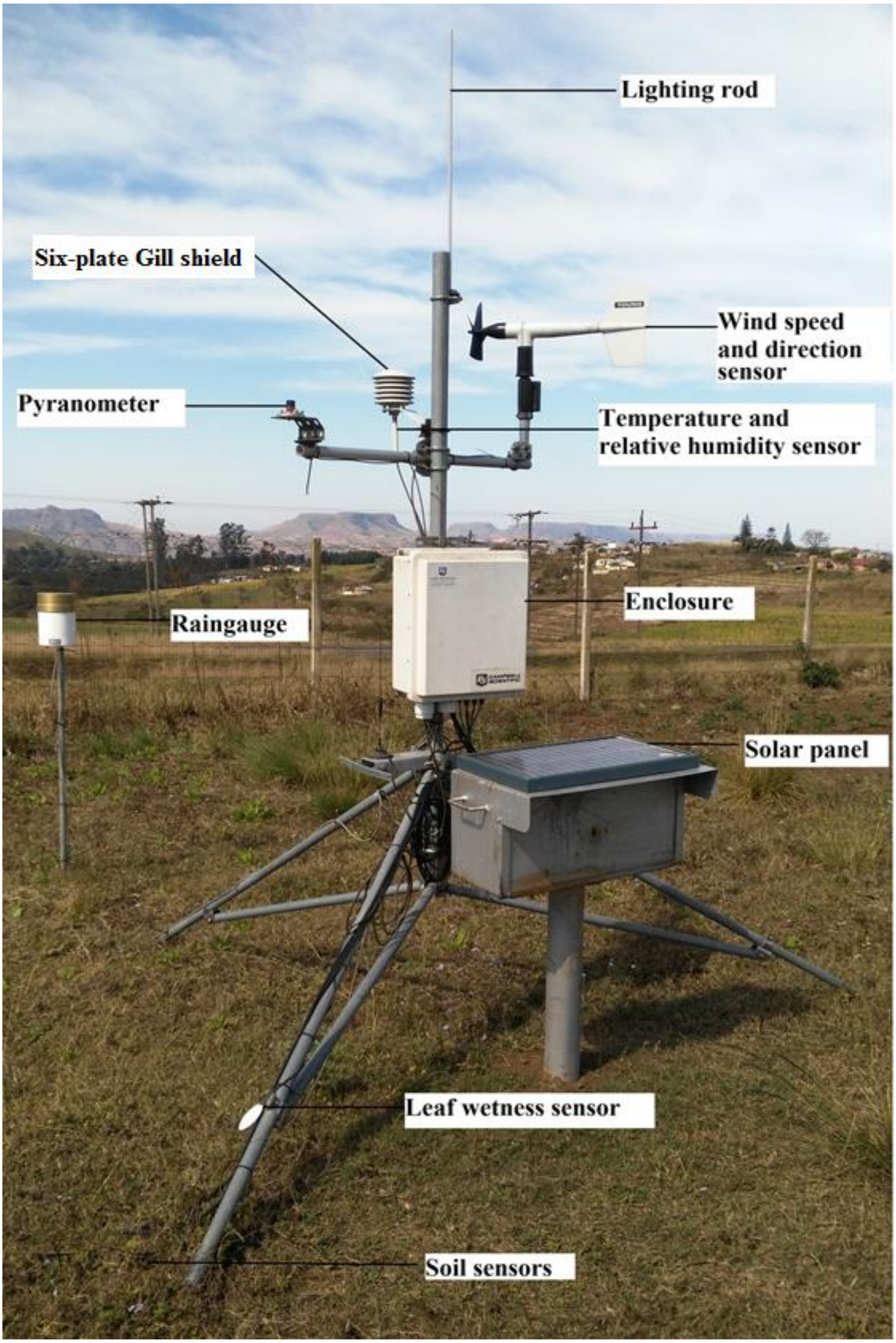


Figure 3.2 Automatic weather station system with additional instruments; one leaf wetness sensor and three volumetric water content sensors (the automatic weather station taken at Swayimana High School in August 2017) Photo: Zibuyile Dlamini.

3.3.1 Equipment and/or sensors used

The AWS system hosted more sensors than the traditional AWS system; consequently, the program (Appendix A) had to be altered to accommodate these extra sensors. The extra sensors included a leaf wetness sensor and three soil sensors that measured five variables, namely volumetric water content, soil temperature, current drain, electric conductivity and relative dielectric permittivity. These sensors recorded measurements at depths 50, 100 and 200 mm. There was an existing soil-water station from a separate project just a few meters away from the AWS system (Appendix B). It hosts 32 soil temperature and soil water potential sensors that measure conditions at different points and depths (150, 300, 600, 900, 1200 mm). The AWS system did not have a sensor that measured soil temperature at the surface so the presence of the soil water station nearby presented benefits. Communication was set up between the soil water station and AWS system in order to obtain all these measurements creating a 'master' and 'slave' relationship between serially connected dataloggers. Table 3.1 explains the communication between dataloggers and provides a detailed description of the other components of the AIM system.

Table 3.1 Details of the various components used for the AIM System

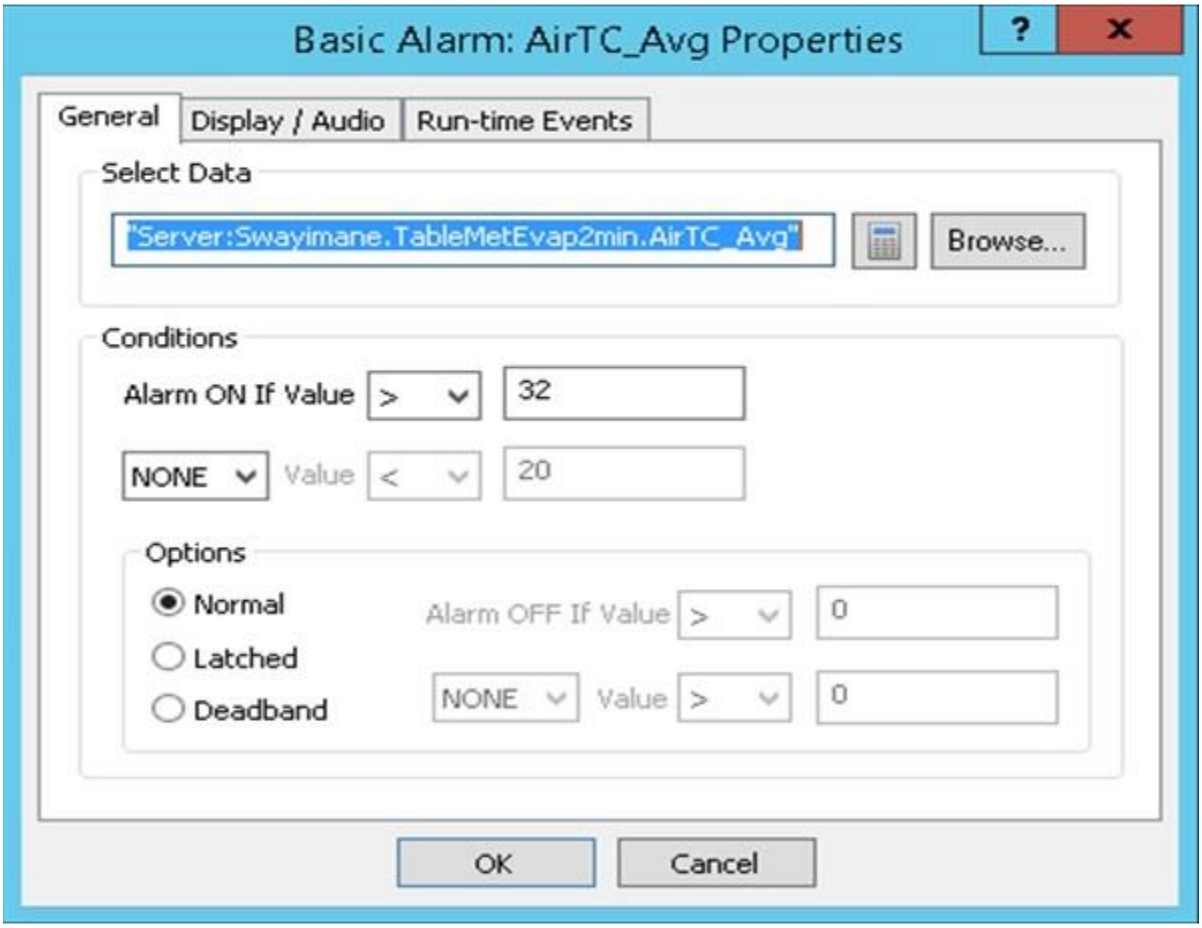
Stations	**Automatic Weather Station**	**Soil station**
Sensors	Wind speed and direction combination sensor: (05103-L RM[1]), Temperature and relative humidity combination sensor:(HC2S3-L[2]) placed in a six plate gill shield, Raingauge: (TR-525[3]), Solar irradiance: (LI-200R M200[4]), Atmospheric pressure: (PTB110[5]), Leaf wetness sensor[6] placed at height of 150 mm, SDI soil sensors with addresses 0, 2, 5: (CS650[7]) soil probe at depths 50, 100, 200 mm	Type T (copper-constantan) thermocouple placed at depths 150, 300, 600, 900 and 1200 mm 253 Soil water potential sensor[7] at depths: 150, 300, 600, 900 and 1200 mm

[1]RM Young Company, Traverse City, Michigan, USA
[2]ROTRONIC AG, Grindelstrasse, Bassersdorf, Switzerland
[3]Texas Electronics, Dallas, Texas, USA
[4]LI-COR, Lincoln, Nebraska, USA
[5]Vaisala, Helsinki, Finland
[6]Model LWS, Decagon Devices Inc., Pullman, Washington State, USA
[7]Campbell Scientific Inc., Logan, Utah, USA

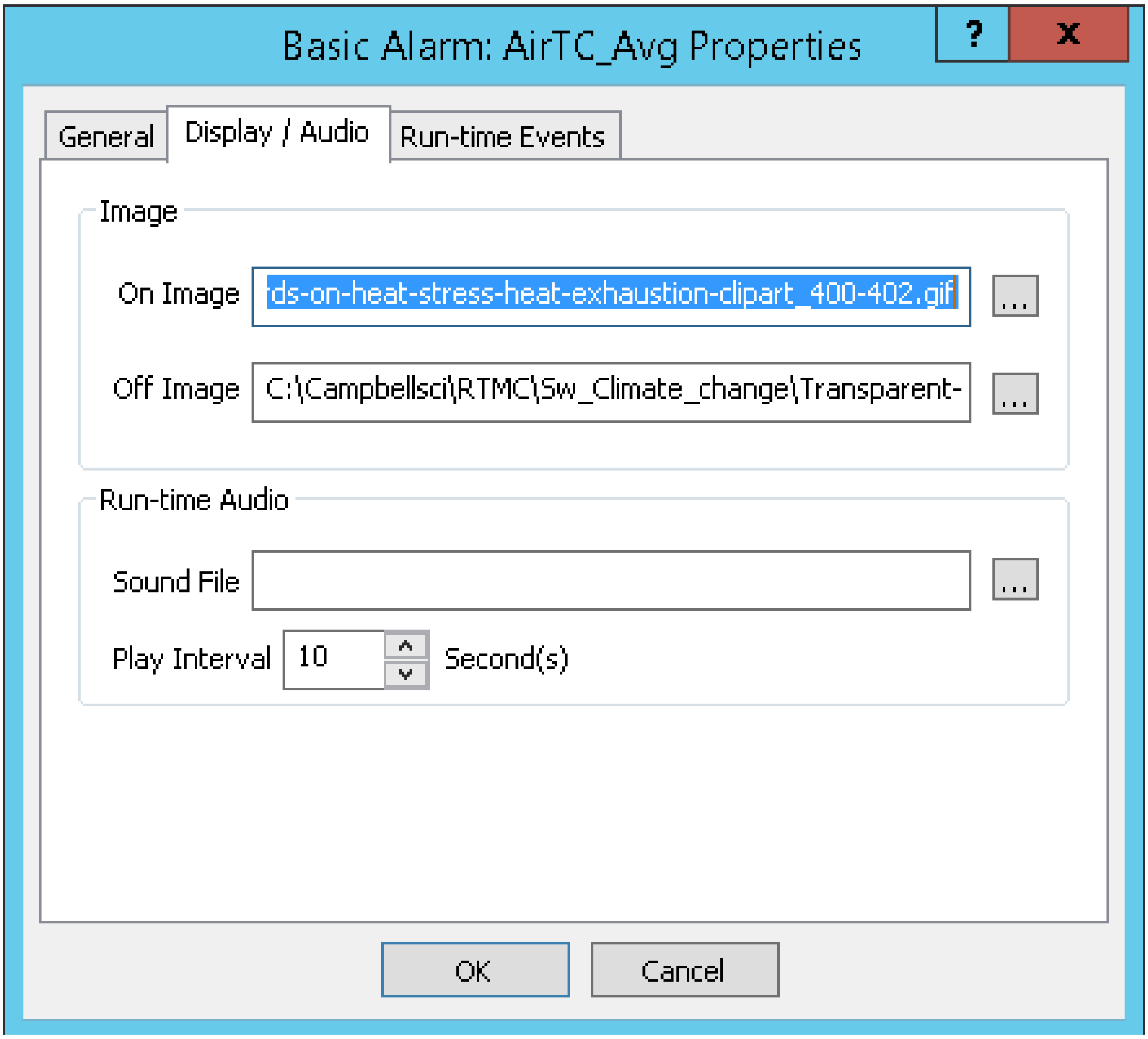
Stations	**Automatic Weather Station**	**Soil station**
Logging equipment and power details	CR3000 datalogger (Pakbus address 618) connected to 80 W solar panel, a regulator and one 7 Ah (12V) battery	CR1000 datalogger (Pakbus address 1) and AM16/32 Multiplexer connected to two 9 Ah (12V) batteries
Communication method	A modem to connect to internet service provider (MTN), a unique IP address (143.128.64.9) is assigned to the server. Collected data are sent to the server and further communicated to the internet	Inter-datalogger direct wiring between CR1000 and CR3000. Data collected was communicated to the internet using the same method
Inter-datalogger communication methods	A three core cable was connected to Com4 on the CR1000 and CR3000 dataloggers, using the baud rate 38400. Tx and Rx port, on Com4 were for transmitting and receiving data respectively	
	Pakbus address 618	Pakbus address 1
	Pakbus Port 3	
	RS232 baud rate 115400	RS232 baud rate 115400
	Tx Rx (com4) 38400	Tx Rx (com4) 38400
Software	LoggerNet version 4.4, RTMC Pro 4.2 which includes RTMC development and RTMC runtime. RTMC Pro was used to develop and design the graphical display for weather information collected by the AWS system. Run-time version allowed for changing public variables values/input locations and toggling graphics and data tables on the display. CSI Web Publisher helps broadcast the designed display to the internet. The graphics and data tables are updated according to the LoggerNet schedule, every five minutes	
Access to data and information visually	Data can be viewed from wi-fi enabled computers in the computer lan. Different screens on the website are displayed and changed every minute so interested scholars can view. Information on data tables can be captured from the internet, stored and opened using Microsoft Excel. Screens can also be viewed on Web-enabled cell phones. Warning text messages are automatically sent by the system when there are possible destructive weather events	

3.4 Webpage set-up

The webpage was set up using LoggerNet RTMC Pro (Real-time Monitoring and Control Software) which allows for development and viewing of data outputs (Campbell Scientific 2016). Various screens were designed and then published on the internet by the CSI Web publisher. There were 19 screens in total under the themes: Weather, Earth's atmosphere, Atmospheric winds, Tropical cyclones, El Niño Southern Oscillation, Drought and Climate change. Screens were designed on the server (virtual machine), which was accessed using a special address and password. LoggerNet RTMC Pro allows the user to display images, draw graphs and data tables and a variety of scales to creatively display the data measured (Campbell Scientific 2016). A basic alarm component is featured in the software and is used to alert scholars of an event when specified conditions are met. For example, the basic alarm feature was used to provide a warning when data were not downloading because it indicated that there was insufficient power or another problem with the system. The modem was set to switch on the first 10 minutes of an hour to download data, thereby updating measurements on the screen. Figure 3.3 shows the settings for the basic alarm component.



(a)



(b)

Figure 3.3 The settings for the alarm image (a) indicating data input and air temperature at which alarm sounds. Image (b) indicating images that display when conditions for alarm are met.

Data were collected and sent to the server through the modem, and the antenna is used to communicate with the server. Data displayed on the server are published on the internet and can be viewed on computer or any web-enabled cell phone. Figure 3.4 is a block diagram describing the complete AIM system set-up.

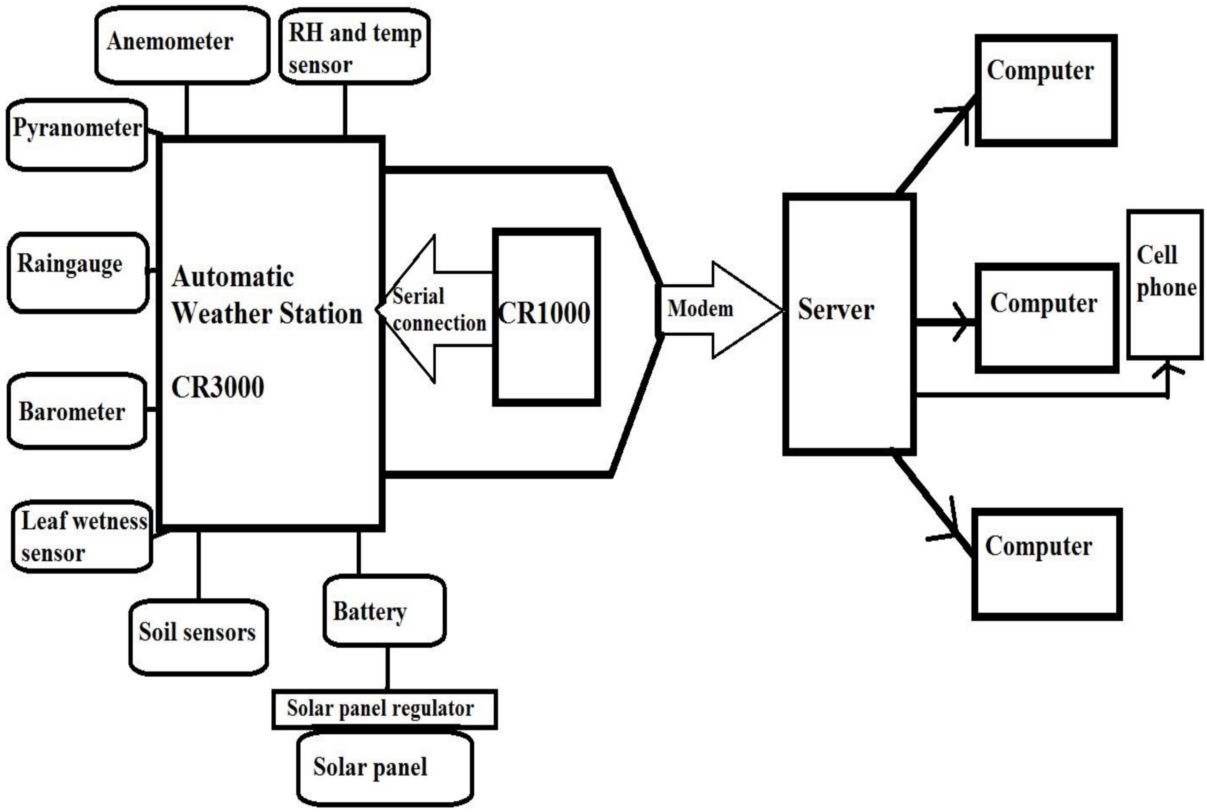


Figure 3.4 Block diagram of AIM system in Swayimana.

3.5 Research methods and techniques

The research has an experimental element to it as an AWS system has not previously been deployed by the University of KwaZulu-Natal to a rural school for such purposes. An integrated research approach was employed in data collection and analysis, although the emphasis was on qualitative more than quantitative research methods. Quantitative research produces information that is presented numerically. This approach includes using closed-ended questionnaires, structured interviews and surveys. It is characterised by less contact and interaction with the target sample, therefore there is less in-depth understanding of the sample's experiences. The nature of the data collection tools used in this approach allows for a larger number of participants, therefore a larger representation of the population (Dawson 2002). Qualitative research is the type of approach that results in descriptive data being produced. It explores people's attitudes, opinions and experiences, and requires more interactions between them and the researcher (Dawson 2002). A deeper understanding can be obtained which can lead to more in-depth and informed conclusions being drawn. The qualitative methods that were used are group interviews and open-ended questions in the questionnaire.

Conducting focus group interviews[8] was chosen because it employs a degree of participant observation that is useful for drawing conclusions. The aim was to obtain an understanding of the perceptions and attitudes of scholars on climate change and mitigation while acquiring statistical data. This required the use of a combined questionnaire[9]. Open-ended questions allow for the audience to write their own answers and are therefore more difficult to analyse and more time-consuming. Closed-ended questions are easier to analyse but provide less detail and do not allow the audience to express themselves fully (Dawson 2002).

Group interviews were conducted in isiZulu which is the primary language of the participants. Questions in questionnaires were bilingual to eliminate misunderstanding and to ensure full comprehension of what was asked. Participants were allowed to answer in their preferred language. Group interviews were based on questionnaires and sought to provide clarity on scholars' opinions.

3.5.1 Research ethical issues

Before the process of qualitative data collection commenced, ethical clearance was sought. This is an important requirement for research that includes administering questionnaires, surveys and conducting focus groups. Ethical clearance permission was granted by the UKZN's Dr Shenuka Singh (Chair of Humanities and Social Sciences Research Ethic Committee) to proceed with data collection provided the project will not be socially, psychologically or physically detrimental to its target sample. Ethical principles to mitigate social harms include voluntary participation, informed consent, confidentiality and anonymity. Approval from the gatekeepers, principal of Swayimana High and Dean of the UKZN School of Agricultural, Earth and Environmental Sciences, was required[10]. Details on the research approach, data collection, storage, and disposal and the dissemination of results were also required. Measures that were to be taken to protect the target sample needed to be expressed to the Chair of HSSREC in order to obtain ethical clearance (Resnik 2015). Declaration of consent for

[8]See Appendix C for group interview guide
[9] See Appendix D and E for questionnaires used
[10]See Appendix F for consent letters of gatekeepers

participants and their parents was a measure taken to protect the target sample[11]. The ethical clearance for the research was granted and assigned a reference number of HSS 1866 016M[12].

3.6 Target population

A target population refers to the entire group of individuals that are a focus of a research study (Banerjee and Chaudhury 2010).The target population were scholars of Swayimana High School. Swayimana High School has 180 Grade 10 to 12 scholars that are studying natural sciences. This study targeted scholars that are studying agriculture, geography, life science, and physical sciences. These scholars were identified as those who were familiar with agro-environmental concepts but might be struggling to grasp their meaning or do not have an in-depth understanding. Some of these scholars do study pure sciences (agriculture, physics and life science) with mathematics, while a larger proportion study geography which is in the category of general studies. The intended sample was half of the target population size (97) but there was a turnout of 55 respondents. The respondent size was narrowed due to time constraints, limited number of computers available and due to not obtaining consent.

3.6.1 Data collection and sampling tools

A baseline study was conducted to obtain the general consensus on climate change so it can act as a bar of comparison. Anyaegbunam et al. (2004) suggest that ‘a baseline study generates information on the levels of awareness, knowledge, attitude and practices of a given population on selected topics in a specific geographic area’. It is performed at the beginning of a study. The first questionnaire was administered to ascertain the number of scholars who had opportunity to influence implementation of agricultural adaptation strategies. These are scholars whose parents or guardians are smallholder farmers in the community. Other questions investigated whether scholars had noticed any agricultural challenges associated with climate change and steps they knew that could overcome them.

Sampling refers to the technique that the researcher uses to select individuals within a target population to participate in the research. It is the opinions and perceptions of these individuals

[11]See Appendix G letter of declaration of consent
[12]See Appendix H ethical clearance letter

from which the researcher can draw conclusions. Simple random sampling within purposive sampling was used, as scholars who were in grade 10-12 were targeted. This method allows each individual in the target population an equal chance to be included in the sample. The type of simple random method was the lottery method. Half of the scholars were sampled for a more accurate idea of their perceptions and experiences. Purposive sampling was used to investigate how the AIM system has influenced the scholars' thinking about climate change and if it has changed their learning experience as a whole. Figure 3.5 shows pictures that were taken during data collection.

(a)

(b)


(c)


(d)

Figure 3.5 (a) Scholars answering baseline questionnaires (b) and (c) group interviews based on questionnaire (d) learning about the different components of the AWS.

3.7 Data analysis

Data analysis methods employed in this study were content and descriptive analysis. Content data analysis uses a systematic, objective and quantitative procedure to examine recorded information. It includes organizing and grouping written information into standard format to allow for conclusions to be drawn. It is most suitable for use when analysing qualitative data resulting from open-ended questionnaires, interviews and surveys. It attaches a numerical value to certain characteristics in a process called coding. This allows for large amounts of information to be reduced, therefore easily interpreted (Burnard et al. 2008). However, a degree of manual analysis was needed in conjunction with content and descriptive analysis. Open-ended questions produce a variety of answers, and require the discretion of the researcher to group them accordingly. The software that was used for analysis is version 22 of Statistical Package for the Social Sciences (SPSS) and Excel. IBM SPSS allows for data processing by the creation of frequency tables, pie charts and bar graphs. It has more features that are useful for this research. Excel was used mainly for analysis of open-ended questions. A graphical display of the results is presented in the form of pie charts, tables and bar graphs. Descriptive statistics were presented as frequencies and percentages.

3.8 Conclusions

The AIM system was set up as part of the fulfilment of the first objective and as a method to fulfil the remaining objectives. The AIM set-up therefore serves a dual purpose. What was particularly interesting was that the AWS hosted extra sensors and was connected to a separate station through a serial connection. There is also an outline of the research procedure that was used in this investigation. Data collection tools used to answer the research question were questionnaires and group interviews. Questionnaires were translated and group interviews conducted in isiZulu, the home language of the target sample. The data collected were mostly qualitative and were analysed descriptively. This chapter also provides a description of the target area which includes climatic and demographic information.

CHAPTER 4: RESULTS OF STUDY

4.1 Introduction

In this chapter the quantitative and qualitative results of the questionnaires and group interviews will be presented. The results from the baseline study fulfil part of the first three objectives of exploring perceptions and opinions of scholars. The description of individual screens from the webpage, with a few screenshots, is presented. The webpage and major themes on individual screens will also be presented. Perceptions of climate change were explored before the AIM system was introduced to examine the gaps in knowledge the system could potentially fill. The response from scholars will be investigated to examine the sustainability of installing the system. The chapter further presents the descriptive results of the data that were collected during the investigation followed by analysis.

4.2 Details of the AIM Swayimana webpage

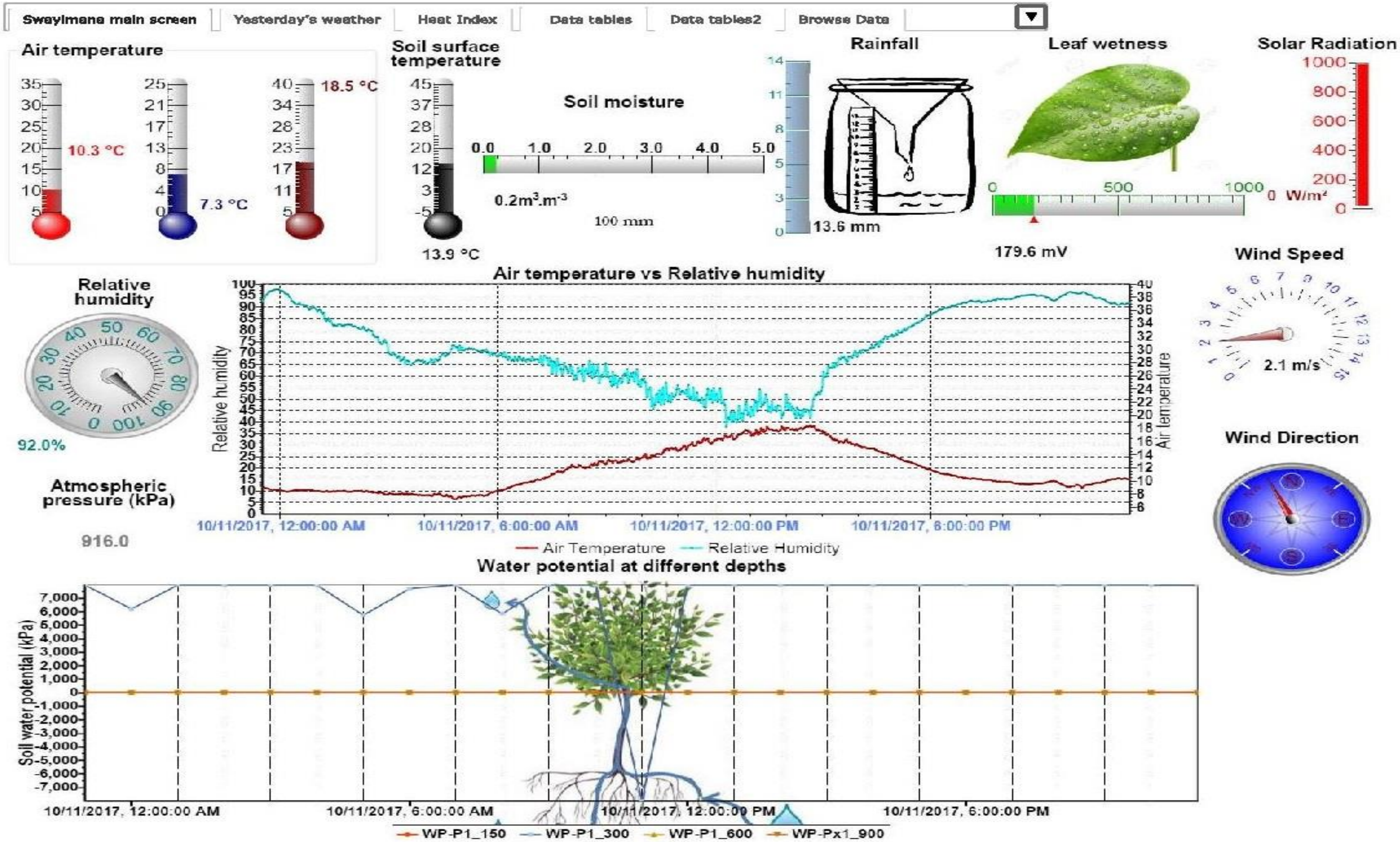
LoggerNet RTMC Pro was used to create a visually rich webpage comprising a total of 19 screens. Screens encompassed geography themes that were included in the Grade 10-12 curriculum. Content from the subject of agriculture and life sciences was also included provided it was linked to the themes in agrometeorology. Data collected are displayed using multi-state alarms, switches, charts and gauges. Details of the webpage displayed at http://agromet.ukzn.ac.za:5355 are described in Table 4.1.

Table 4.1 Details of the various screens displayed that constitute the web-based system

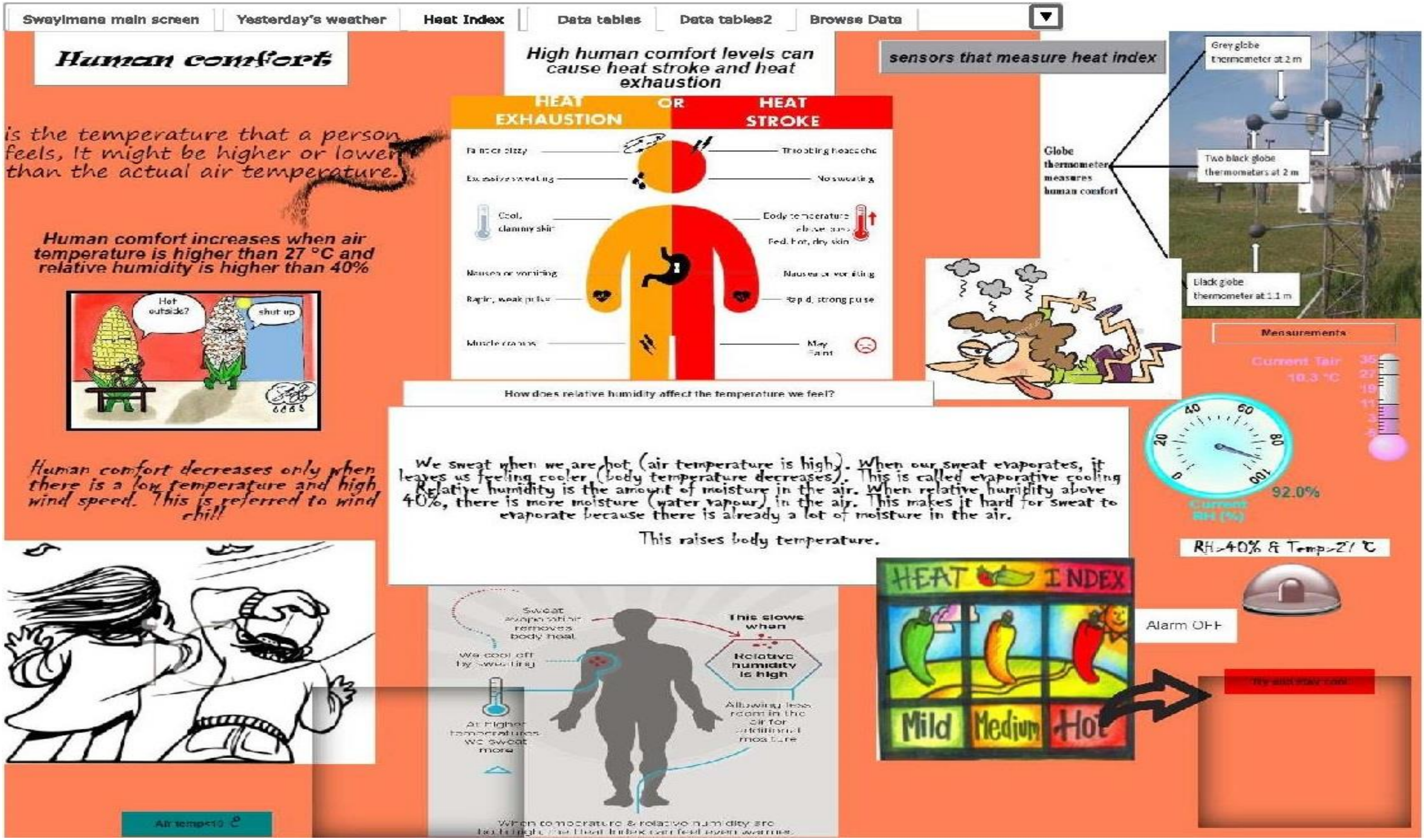
Screen name	**Details of screen**
Main weather screen	This screen displays the weather at Swayimana in real time. It displays all the measurements the AIM system collects. Temporal graphs comparing air temperature and relative humidity on the same system of axis as well as soil water potential at different depths are included. It has a heat index screen explaining human comfort and the conditions that influence it. There is a screen dedicated to two-minute, hourly and daily data tables. The screen also provides warnings of adverse real-time weather conditions.

Screen name	Details of screen
Earth’s atmosphere	The definition and composition of Earth’s atmosphere. Displays of the different spheres and the distance they are from the Earth. The second screen is the global air circulation to give a better understanding of climate systems. This screen shows relationship between air circulation and biomes.
Atmospheric winds	Sheds light on different types of planetary winds, the Coriolis force and the Inter-Tropical Convergence Zone. Includes a Berg winds screen dedicated to define the term and conditions that occur and are with which they associated.
El Niño Southern Oscillation	The El Niño screen defines the phrase and explains the processes that take place before it occurs. It includes a graph displaying the Oceanic Niño Index during El Niño and La Niña phases.
Tropical cyclones	Conditions associated with tropical cyclones and measurements important for detecting it. It shows the impacts of floods on crops and livestock. A bar graph of rainfall accumulation over weeks and an alarm that is set up to measure rainfall and soil water is displayed. Processes that take place in the soil dictated by the amount of oxygen available to plant roots (i.e. nitrification and denitrification) are also concluded.
Droughts	Defines droughts and their direct and consequential effects. A graph displays soil water potential and soil water content on different sets of axes versus time. The desertification screen relates the two phenomena, areas at risk and displays soil temperature measurements.
Climate change	Historical data and temporal graph displaying CO_2 and temperature anomaly from 1880. Specifically, the progressive rise of global air temperature and corresponding CO_2 concentration since 1880. Anthropogenic influenced causes of climate change and global warming are detailed. This screen also includes immediate hydrological, biological and environmental effects of increase in global air temperature.

(a)

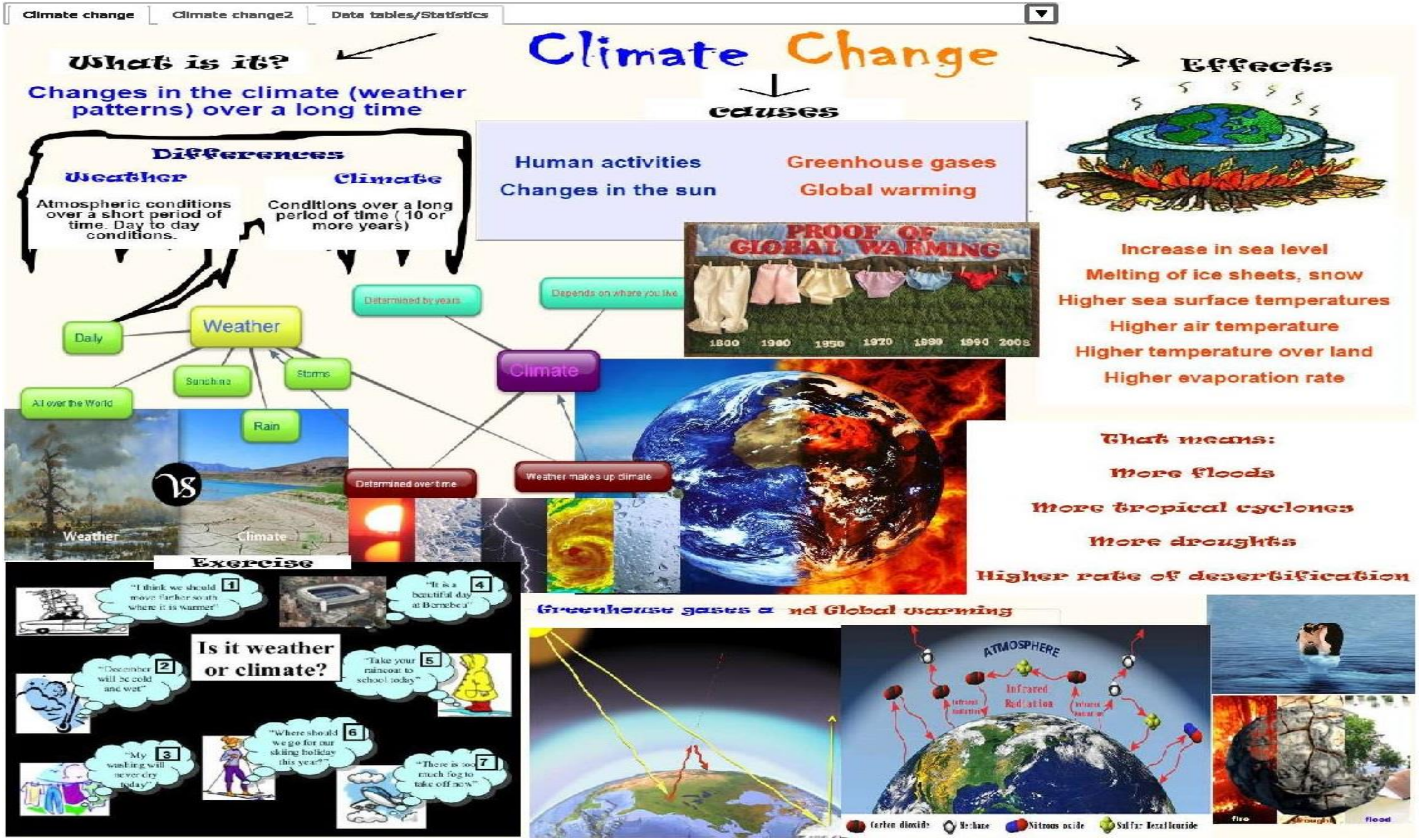

Swaylmane main screen
Yesterday's weather
Heat Index
Data tables
Data tables2
Browse Data
Air temperature
10.3 °C
7.3 °C
18.5 °C
Soil surface temperature
13.9 °C
Soil moisture
0.2m³.m⁻³
100 mm
Rainfall
13.6 mm
Leaf wetness
179.6 mV
Solar Radiation
0 W/m²
Relative humidity
92.0%
Atmospheric pressure (kPa)
916.0
Air temperature vs Relative humidity
Relative humidity
Air temperature
10/11/2017, 12:00:00 AM
10/11/2017, 6:00:00 AM
10/11/2017, 12:00:00 PM
10/11/2017, 6:00:00 PM
Air Temperature
Relative Humidity
Wind Speed
2.1 m/s
Wind Direction
Water potential at different depths
Soil water potential (kPa)
WP-P1_150
WP-P1_300
WP-P1_600
WP-Px1_900

(b)



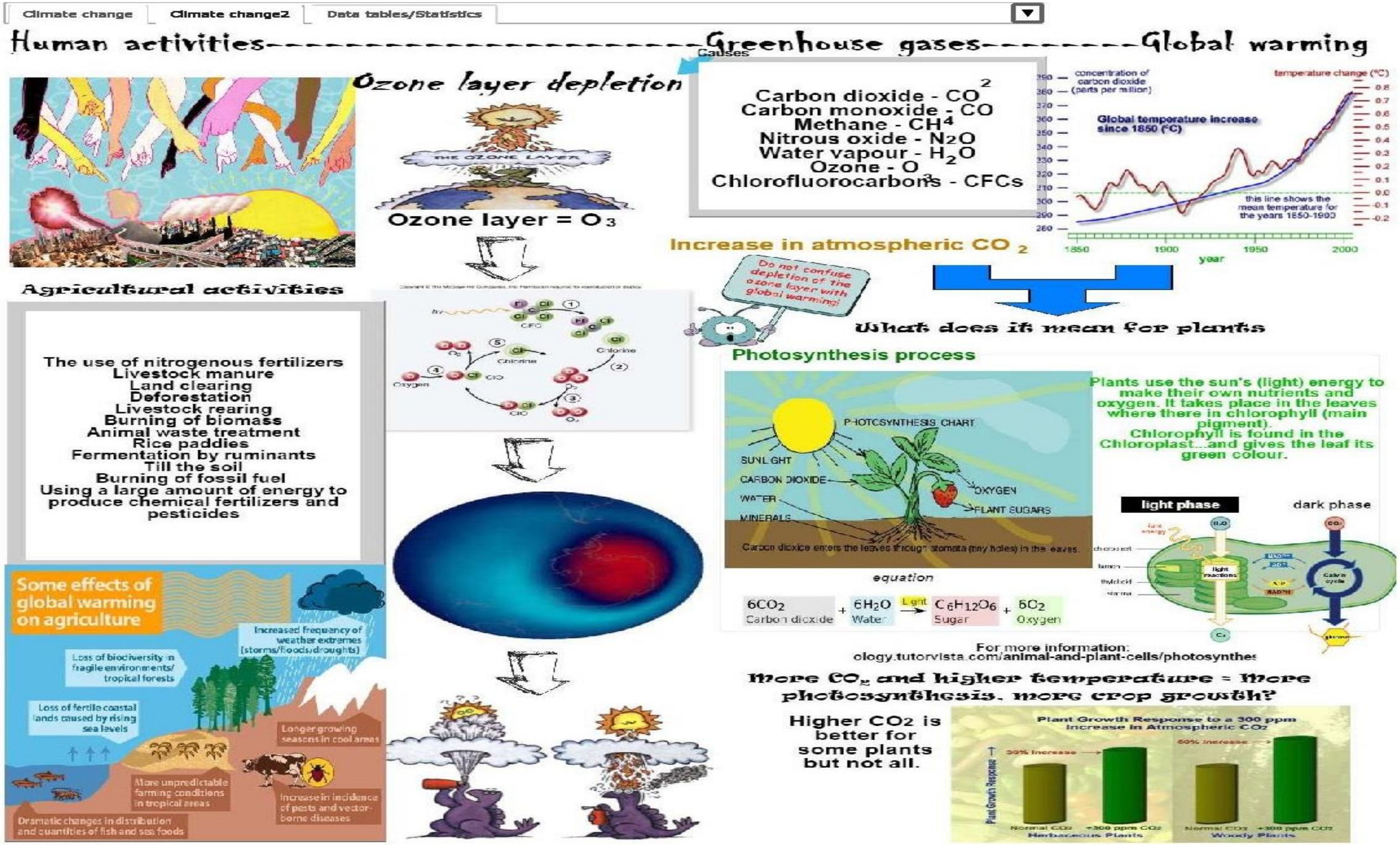
Swaylmana main screen
Yesterday's weather
Heat Index
Data tables
Data tables2
Browse Data
Human comfort
is the temperature that a person feels, It might be higher or lower than the actual air temperature.
Human comfort increases when air temperature is higher than 27 °C and relative humidity is higher than 40%
Hot outside?
shut up
Human comfort decreases only when there is a low temperature and high wind speed. This is referred to wind chill
High human comfort levels can cause heat stroke and heat exhaustion
HEAT EXHAUSTION
OR
HEAT STROKE
Excessive sweating
Cool, clammy skin
Nausea or vomiting
Rapid, weak pulse
Muscle cramps
Throbbing headache
No sweating
Nausea or vomiting
Rapid, strong pulse
May faint
How does relative humidity affect the temperature we feel?
We sweat when we are hot (air temperature is high). When our sweat evaporates, it leaves us feeling cooler (body temperature decreases). This is called evaporative cooling
Relative humidity is the amount of moisture in the air. When relative humidity above 40%, there is more moisture (water vapour) in the air. This makes it hard for sweat to evaporate because there is already a lot of moisture in the air.
This raises body temperature.
sensors that measure heat index
Globe thermometer measures human comfort
Grey globe thermometer at 2 m
Two black globe thermometers at 2 m
Black globe thermometer at 1.1 m
Measurements
92.0%
RH>40% & Temp>27 °C
HEAT INDEX
Mild
Medium
Hot
Alarm OFF
This slows when
Relative humidity is high
We cool off by sweating
At Higher temperatures we sweat more

(c)



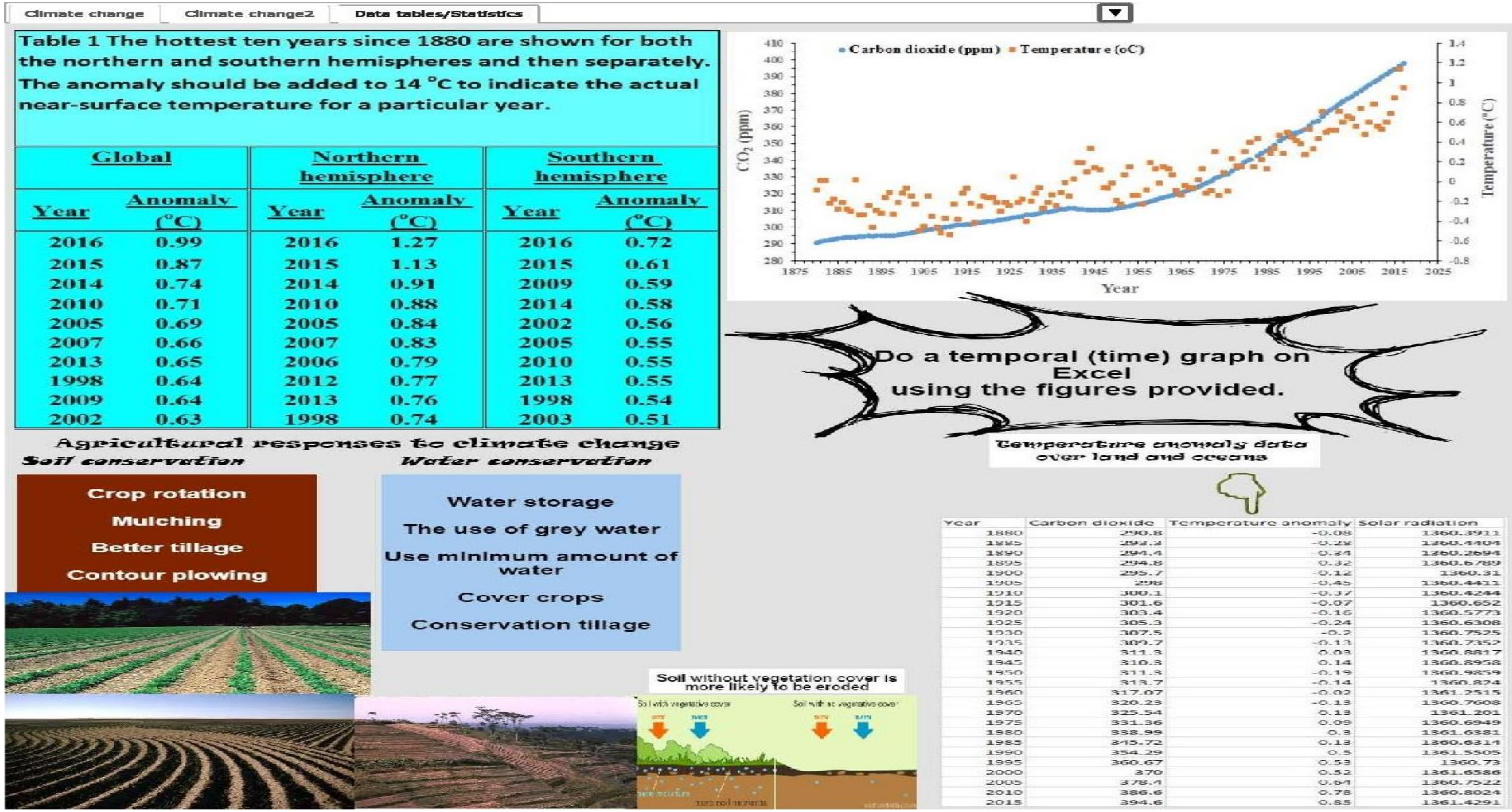
Climate change
Climate change2
Data tables/Statistics
Climate Change
What is it?
Changes in the climate (weather patterns) over a long time
Differences
Weather
Atmospheric conditions over a short period of time. Day to day conditions.
Climate
Conditions over a long period of time (10 or more years)
causes
Human activities
Changes in the sun
Greenhouse gases
Global warming
PROOF OF GLOBAL WARMING
1800 1900 1950 1970 1980 1990 2008
Effects
Increase in sea level
Melting of ice sheets, snow
Higher sea surface temperatures
Higher air temperature
Higher temperature over land
Higher evaporation rate
That means:
More floods
More tropical cyclones
More droughts
Higher rate of desertification
Weather
Daily
Sunshine
Storms
All over the World
Rain
Determined by years
Depends on where you live
Climate
Determined over time
Weather makes up climate
VS
Weather
Climate
Exercise
Is it weather or climate?
"I think we should move farther south where it is warmer" 1
"December will be cold and wet" 2
"My washing will never dry today" 3
"It is a beautiful day at Bernebeu" 4
"Take your raincoat to school today" 5
"Where should we go for our skiing holiday this year?" 6
"There is too much fog to take off now" 7
Greenhouse gases and Global warming
ATMOSPHERE
Infrared Radiation
Carbon dioxide
Methane
Nitrous oxide
Sulfur Hexafluoride
fire
drought
flood

(d)



Climate change
Climate change2
Data tables/Statistics
Human activities----------------------------Greenhouse gases----------Global warming
Causes
Ozone layer depletion
Ozone layer = O3
Carbon dioxide - CO2
Carbon monoxide - CO
Methane - CH4
Nitrous oxide - N2O
Water vapour - H2O
Ozone - O3
Chlorofluorocarbons - CFCs
Global temperature increase since 1850 (°C)
concentration of carbon dioxide (parts per million)
temperature change (°C)
this line shows the mean temperature for the years 1850-1900
year
Increase in atmospheric CO 2
Agricultural activities
The use of nitrogenous fertilizers
Livestock manure
Land clearing
Deforestation
Livestock rearing
Burning of biomass
Animal waste treatment
Rice paddies
Fermentation by ruminants
Till the soil
Burning of fossil fuel
Using a large amount of energy to produce chemical fertilizers and pesticides
Do not confuse depletion of the ozone layer with global warming!
What does it mean for plants
Photosynthesis process
Plants use the sun's (light) energy to make their own nutrients and oxygen. It takes place in the leaves where there in chlorophyll (main pigment).
Chlorophyll is found in the Chloroplast...and gives the leaf its green colour.
PHOTOSYNTHESIS CHART
SUNLIGHT
CARBON DIOXIDE
WATER
MINERALS
OXYGEN
PLANT SUGARS
Carbon dioxide enters the leaves through stomata (tiny holes) in the leaves.
light phase
dark phase
equation
6CO2 Carbon dioxide + 6H2O Water → Light C6H12O6 Sugar + 6O2 Oxygen
For more information:
ology.tutorvista.com/animal-and-plant-cells/photosynthes
More CO2 and higher temperature = more photosynthesis, more crop growth?
Higher CO2 is better for some plants but not all.
Plant Growth Response to a 300 ppm Increase in Atmospheric CO2
30% Increase
60% Increase
Normal CO2
+300 ppm CO2
Herbaceous Plants
Woody Plants
Some effects of global warming on agriculture
Increased frequency of weather extremes (storms/floods/droughts)
Loss of biodiversity in fragile environments/ tropical forests
Loss of fertile coastal lands caused by rising sea levels
Longer growing seasons in cool areas
More unpredictable farming conditions in tropical areas
Increase in incidence of pests and vector-borne diseases
Dramatic changes in distribution and quantities of fish and sea foods

(e)



Global		Northern hemisphere		Southern hemisphere	
Year	Anomaly (°C)	Year	Anomaly (°C)	Year	Anomaly (°C)
2016	0.99	2016	1.27	2016	0.72
2015	0.87	2015	1.13	2015	0.61
2014	0.74	2014	0.91	2009	0.59
2010	0.71	2010	0.88	2014	0.58
2005	0.69	2005	0.84	2002	0.56
2007	0.66	2007	0.83	2005	0.55
2013	0.65	2006	0.79	2010	0.55
1998	0.64	2012	0.77	2013	0.55
2009	0.64	2013	0.76	1998	0.54
2002	0.63	1998	0.74	2003	0.51

Year	Carbon dioxide	Temperature anomaly	Solar radiation
1880	290.8	-0.08	1360.3911
1885	293.3	-0.28	1360.4404
1890	294.4	-0.34	1360.2694
1895	294.8	0.32	1360.6789
1900	295.7	-0.12	1360.31
1905	298	-0.45	1360.4411
1910	300.1	-0.37	1360.4244
1915	301.6	-0.07	1360.652
1920	303.4	-0.16	1360.5773
1925	305.3	-0.24	1360.6308
1930	307.5	-0.2	1360.7525
1935	309.7	-0.13	1360.7352
1940	311.3	0.03	1360.8817
1945	310.3	0.14	1360.8958
1950	311.3	-0.19	1360.9859
1955	313.7	-0.14	1360.824
1960	317.07	-0.02	1361.2515
1965	320.23	-0.13	1360.7608
1970	325.54	0.13	1361.201
1975	331.36	0.09	1360.6949
1980	338.99	0.3	1361.6381
1985	345.72	0.13	1360.6314
1990	354.29	0.5	1361.5505
1995	360.67	0.53	1360.73
2000	370	0.52	1361.6586
2005	378.4	0.64	1360.7522
2010	386.6	0.78	1360.8024
2015	394.6	0.85	1361.4291

Figure 4.1 Screens from website, (a) Main weather screen (b) heat index (c) climate change main screen (d) 2nd screen and (e) data table screen.

4.2.1 The web-based system's effect on scholars' learning

Agro-environmental terms were presented on the website using images and icons. Before exposure, the least understood terms were soil water potential, heat index and solar irradiance at 0 %, 2.8 % and 5.6 % respectively. Air temperature and wind speed and direction were chosen by 30.6 % of respondents indicating they were the most recognised terms. The number of agro-environmental concepts respondents understood ranged from 0-4 out of 6. Respondents' understanding of terms increased significantly after the introduction of the web-based system. Figure 4.2 shows comparison of respondents' understanding of term before and after the introduction of the web-based system.

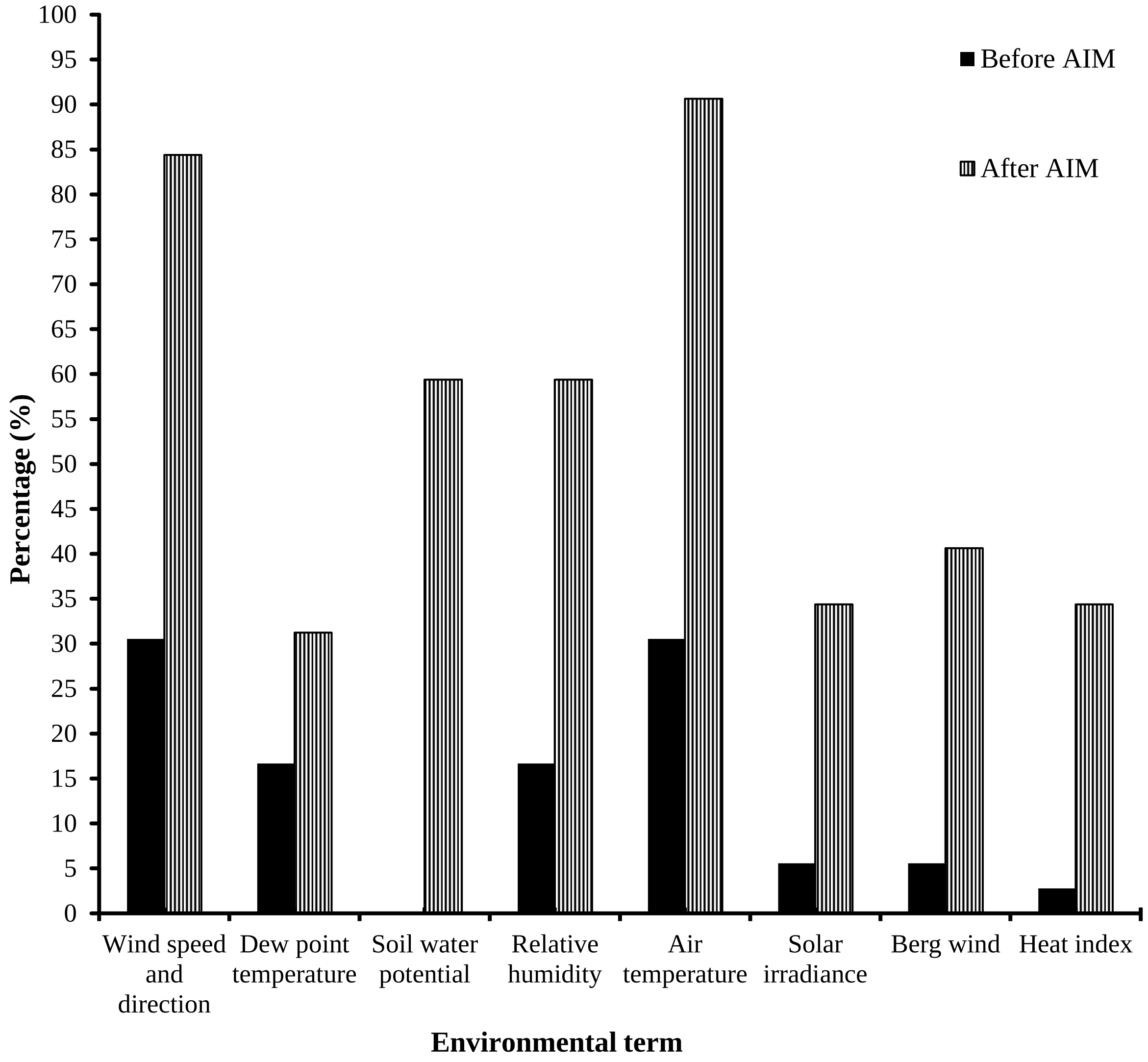


Figure 4.2 Bar graph indicating scholars' grasp of environmental concepts before and after AIM system exposure (n=55).

The number of concepts understood after exposure to the AIM system ranged from 2-6, meaning the minimum and the maximum number of terms understood had increased to 2 and 6 respectively. Respondents were introduced to new earth and atmospheric processes. They were particularly excited to learn about the process of ozone depletion. All respondents appeared to have met at least one environmental term for the first time. New terms learnt include chlorofluorocarbons, mulch, precipitation, cloud cover, soil water potential, and leaf wetness. Phenomena learnt were global warming, climate change, Berg winds, El Niño and La Niña.

Some 91 % of respondents attributed their understanding of terms to the AIM system while 65.5 % indicated that they understood most of what was displayed. The majority (94.5 %) of the respondents recognised that the content on the website was related to their studies. They identified subject matter from agriculture, geography, physical sciences and life sciences. Further, 96.4 % were of the opinion that this method of learning would improve their grasp of the content of their subjects. They further attributed this to the design and graphical nature of the display. Agriculture (science stream) scholars learned geographical concepts, for example different atmospheric winds and global weather phenomena. Geography (general studies) scholars understood their syllabus and the relationship between different areas of subject matter better. They expressed a higher level of confidence to write their final examinations for the year.

Prior to the introduction of the AIM system 80 % respondents were able to read the minimum and maximum of graphs while 92 % respondents stated that they were able to interpret line graphs. Some 94.6 % indicated that it improved their ability to read and analyse descriptive statistical data on the computer. The website helped expose them to different types of graphs. It further taught them important aspects of graphs, particularly what qualifies variables to be on the x and y axis. They were able to find relationships and interactions between variables on the same system of axes. The graphical display improved their appreciation of interactions between different agro-environmental data.

4.3 Results of baseline study

To fulfil the second objective, the baseline study investigated the knowledge respondents had initially, before the system was introduced. Table 4.1 displays percentage of respondents who have internet access, land and livestock compared to grade. Some 83.2 % and 71.9 % have access to land and rear livestock respectively.

Table 4.2 Results of closed ended baseline questions expressed as percentage

		Grade			
		Grade 10	Grade 11	Grade 12	Average
Do you have access to the internet?	Yes	38.9%	33.3%	76.9%	**49.7%**
	No	61.1%	66.7%	23.1%	**50.3%**
Do you have land at home that your family farms?	Yes	88.9%	91.7%	69.2%	**83.2%**
	No	11.1%	8.3%	30.8%	**16.8%**
Do you keep livestock?	Yes	77.8%	91.7%	46.2%	**71.9%**
	No	22.2%	8.3%	53.8%	**28.1%**

Some 63.6 % of respondents indicated that school was their only source of climate change information while 78.1 % coupled school with another source. Figure 4.3 is a pie chart representing sources of climate change information used by scholars.

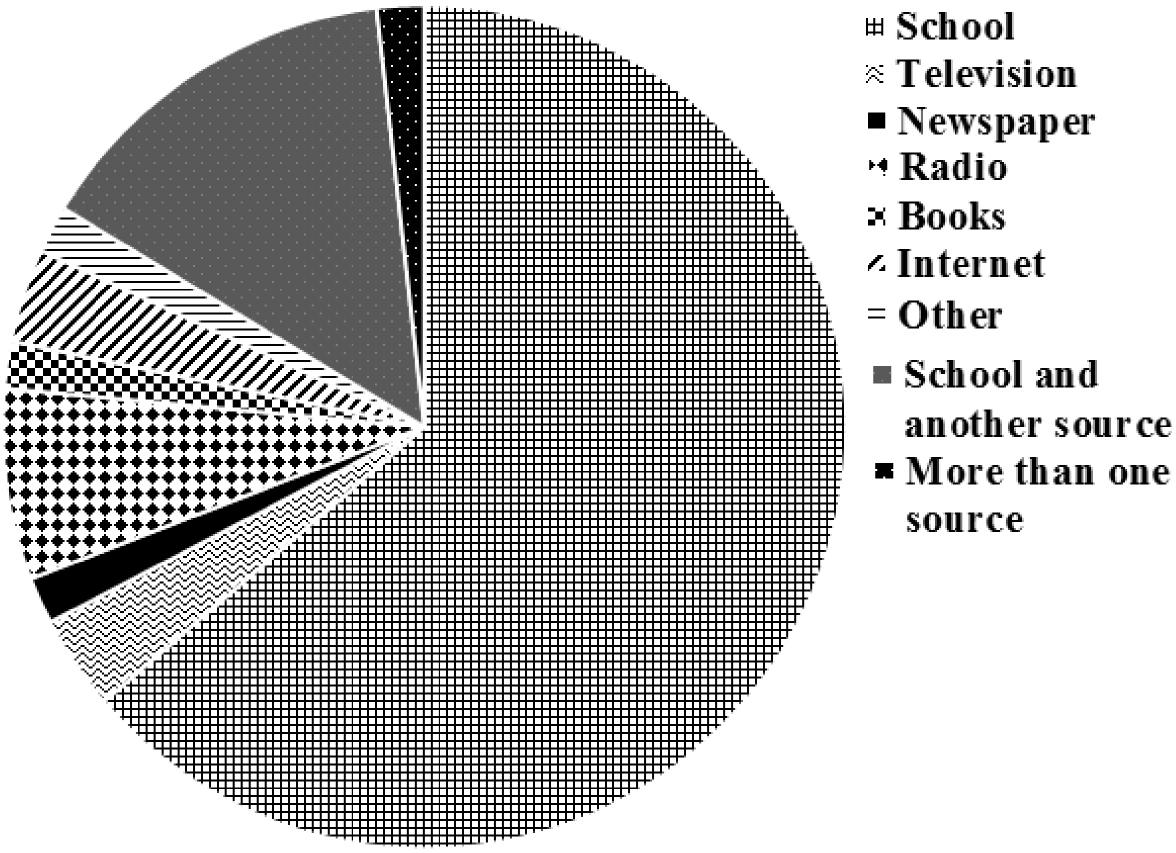


Figure 4.3 Pie chart indicating sources of climate change information.

The radio was the information source that 7.3 % of the respondents received their climate change ideas from. Some 3.6 % respondents chose television and the internet as their main source while 1.8 % gained their information from books, the newspaper and other sources. It is important to note 49.7 % claimed that they have internet access. The other sources chosen by 1.8 % respondents were not specified. Respondents who answered 'no' to knowing about climate change were (72.7 %) those who indicated school was their only source of climate change information.

A significant percentage (20 %) answered 'no' to knowing about climate change but had heard about it through different sources. As expected about 72.7 % of these indicated they had heard of climate change through school. The remaining 27.3 %, who did not know about it, chose television, internet, school and other sources, in equal proportion. Table 4.3 is a cross tabulation of information source and whether or not respondents had knowledge about climate change.

Table 4.3 Comparing knowledge of climate change and information source

		Do you know about climate change?	
		Yes	No
Where did you get information about climate change from?	School	61.4%	72.7%
	Television	2.3%	9.1%
	Newspaper	2.3%	0.0%
	Radio	9.1%	0.0%
	Books	2.3%	0.0%
	Internet	2.3%	9.1%
	Other	2.3%	0.0%
	School and other source	15.9%	9.1%
	Combination of other sources	2.3%	0.0%
Total		100.0%	100.0%

4.3.1 Perceptions of weather and climate change before AIM system

Some 80 % of respondents noted that they knew about climate change and also expressed their knowledge. Some of those that indicated 'yes' did not give comprehensive answers when asked to indicate their understanding of it. The majority (80 %) of respondents, including those who claimed did not know about climate change, viewed it as a very important issue that needs to be addressed. Opinions on the importance of climate change were grouped into 'comprehensive answer', these are weather and climate related, 'agriculture related' and 'incomprehensive answer'. Only 20 % considered climate change to be important because of its relationship with agriculture and food security. Some 14.5 % focused on the impacts it has on the three spheres (social, environment and economy) while 45 % were classified as 'incomprehensive answers', which included just 'having knowledge'. Appendix I shows the exact answers that were given by selected respondents that indicate their attitudes towards the issue of climate change.

To analyze what respondents understood about climate change, responses were grouped into 'Definition', 'causes', 'effects', 'mitigation', 'adaptation', 'not related' and 'no answer'. The majority (31 %) of respondents fell into the 'no answer' category which includes unclear and incomplete answers. Some 23.6 % and 20 % respondents answered on effects and definitions of climate change respectively. Further, 16.4 % indicated the causes while 9.1 % gave unrelated answers. The latter gave an indication that respondents confused climate change with ozone depletion. A minute 5 % of respondents indicated a knowledge of mitigation and adaptation strategies. Their responses included mitigation and adaptation which predominantly were about the other aspects of climate change. Figure 4.4 depicts their perceptions on aspects of climate change.

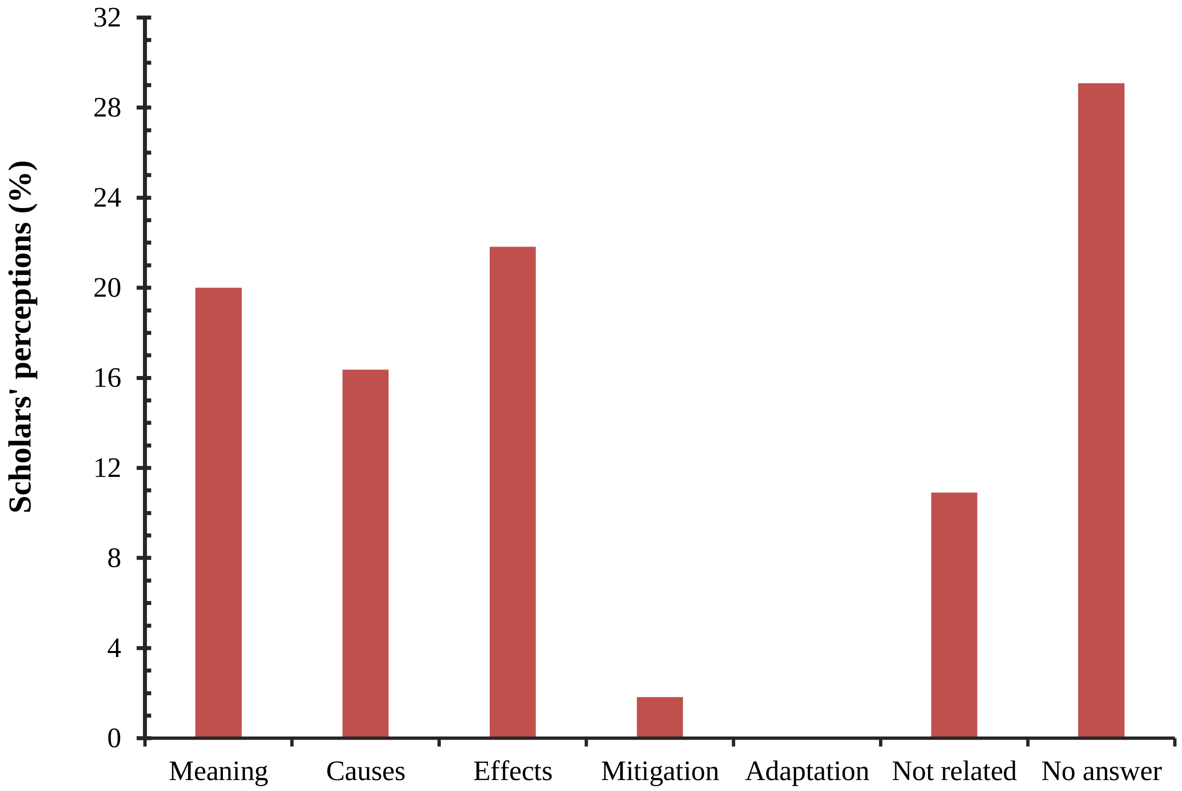


Figure 4.4 Scholars' perceptions on the aspects of climate change.

Table 4.4 are selected quotes from respondents expressing their knowledge on different climate change aspects. Responses in isiZulu were translated into English and minor grammatical errors were corrected according to discretion of the researcher.

Table 4.4 Indicating perceptions of climate change grouped accordingly

Do you know about climate change? What do you understand about climate change?	
Aspects of climate change	**Quotes on perception**
Definition	• "These are the changes of weather condition which damages the ozone layer on our planet earth" • "It is the change in the atmosphere" • "It is the change in a weather pattern of an area" • "It is a change of weather certainty because of human activity" • "Changes of weather in the atmosphere and I think it is why the temperature keeps on changing. The causes of climate change is the human activities" • "Is that climate change is the change that happens daily in the atmosphere and down to earth or it is the way temperature whether it is hot/cold in a particular day" • "It is when the weather changes as well as the water cycle" • "Fluctuating temperatures" • "The changing of the weather and seasons"
Causes	• "Caused by air pollution" • "That is caused by greenhouse gases which are CO^2 and Methane" • "That the blanket is being damaged by the chemicals that the people are making on earth" • "It caused by big factory" • "It can be affected by greenhouse gases, deforestation, which increase the CO^2 levels in the atmosphere" • "It is caused by different types of gases emitted to the atmosphere especially fossil fuels" • "It is when we are not allowed to burn fossil fuels, burning forest, coal and because it destroy the atmosphere" • "Climate change is caused by greenhouse effects and global warming. Climate change can be caused by fossil fuels from factories" • "I know that climate change happens when we burn things on earth then the steam goes up then the weather changes"
Effects	• "That it will be more disturbing in the next coming years" • "Changing of climate can affect a lot of resources in the whole world e.g. when there is drought many animals would die and rivers will dry and plants may die also"

	• "The climate change is changing into are global warming and sometimes the climate change destroy our growing crops" • "Heavy rainfall and floods" • "It affects the agricultural activities"
Mitigation	• "We can prevent it by recycling, stop deforestation and changing farming strategies"
Unrelated	• "There are different season spring, summer, autumn winter" • "We get it from weather balloons" • "Human activities can cause ozone depletion and air pollution, water pollution" • "It is caused by acid rain"

The majority did not indicate much knowledge on adaptation and mitigation. A significant percentage (47.3 %) indicated that they did not use the climate change information they have obtained in everyday life. Some 27.2 % respondents said that they used their knowledge by educating their peers whereas 25.5 % of other uses included refraining from burning waste, not using perfumes and recycling. Some answered 'by reducing air pollution' but were not specific as to how they reduced it.

4.3.1.1 Impacts of adverse weather

Respondents indicated that climate change has a noticeable effect on weather and agricultural elements in the study area. There were 30, 29 and 28 counts of increase in dry spells, decrease in rainfall and increase in air temperature respectively (Table 4.5). There were counts of 25, 25 and 24 increase in plant pests, livestock mortality and livestock forage. Under steps taken for reducing negative impacts, counts ranged from 9-2. Nine respondents noticed steps had been taken to overcome the shifting of planting season challenge. Two respondents noticed steps had been taken to overcome the challenges of rainfall, rainfall frequency and frost. Table 4.5 also documents the farming challenges that respondents noticed their parents/grandparents face.

Table 4.5 Responses of the effects of adverse weather associated with climate change

Effect	Increase	Decrease	Steps taken to reduce negative effects	I have not noticed any challenge	Total count (n)
Rainfall	19	29	2	4	54
Rainfall frequency	6	12	2	21	41

Effect	Increase	Decrease	Steps taken to reduce negative effects	I have not noticed any challenge	Total count (n)
Temperature	28	17	5	3	53
Frost	11	14	2	23	50
Dry spells	30	9	6	7	52
Soil erosion	19	16	5	12	52
Soil moisture	17	16	5	12	50
Shifting planting seasons	21	7	9	16	53
Changes in plant growth	19	19	3	11	52
Plant pests	25	12	4	13	54
Plant diseases	16	16	5	12	49
Livestock forage	24	17	7	8	56
Livestock diseases	22	12	6	12	52
Livestock pests	19	15	4	14	52
Livestock mortality	25	8	5	12	50
Other	6	3	1	19	29

4.3.2 Scholars preference on weather information

Television was the main source of weather information with the internet and radio being the least used sources. Corresponding to 96.4 %, equivalent to a number of 53 respondents indicated an interest in internet-based weather services (as indicated in Table 4.8). However, the internet was chosen as a weather source 5 times. Respondents were most interested in rain, sunshine and maximum temperature, and based their daily decisions on these three factors. More local information was desired in a weather service provider.

Table 4.6 Presenting respondents' preferences of weather information

Where do you usually get your weather information from?							
Newspaper		Television		Internet		Radio	
0		50		5		4	
What aspects of weather are you usually interested in?							
Max temp	Min temp	Rain	Wind speed	Cloud	Sunshine	Frost	Berg winds
28	21	33	11	13	32	4	3
Which of the following weather aspects shape your day-to-day decisions?							
Max temp	Min temp	Rain	Wind speed	Cloud	Sunshine		
13	20	19	3	5	17		
Are there any things you want from weather services that you do not usually get?							
More local information	Clearer symbols	Detailed information	Pollution indicator	Sunburn warnings			
39	9	10	19	25			

4.4 Assessing the usability, effectiveness and sustainability of the system based on scholars response

4.4.1 Usability of web-based system

Respondents found the web-based system easy to use and the display easy to understand. The website contains instructions on how to export data to Notepad and display it on Excel. Some 74.5 % downloaded data but 81.8 % found downloading data from the website difficult. Respondents understood what agro-environmental concept was represented in the real-time data collected because of the icons and images used. Some 94.5 % confirmed that reading ability was not essential because the graphics illustrated information being presented.

4.4.2 Effectiveness of web-based system

The system improved 92.7 % of respondents' awareness of ranges in weather elements, and taught 89 % of them about climate change and global warming aspects (Figure 4.5). A majority of 96.4 % felt that it made a positive difference in their statistical literacy.

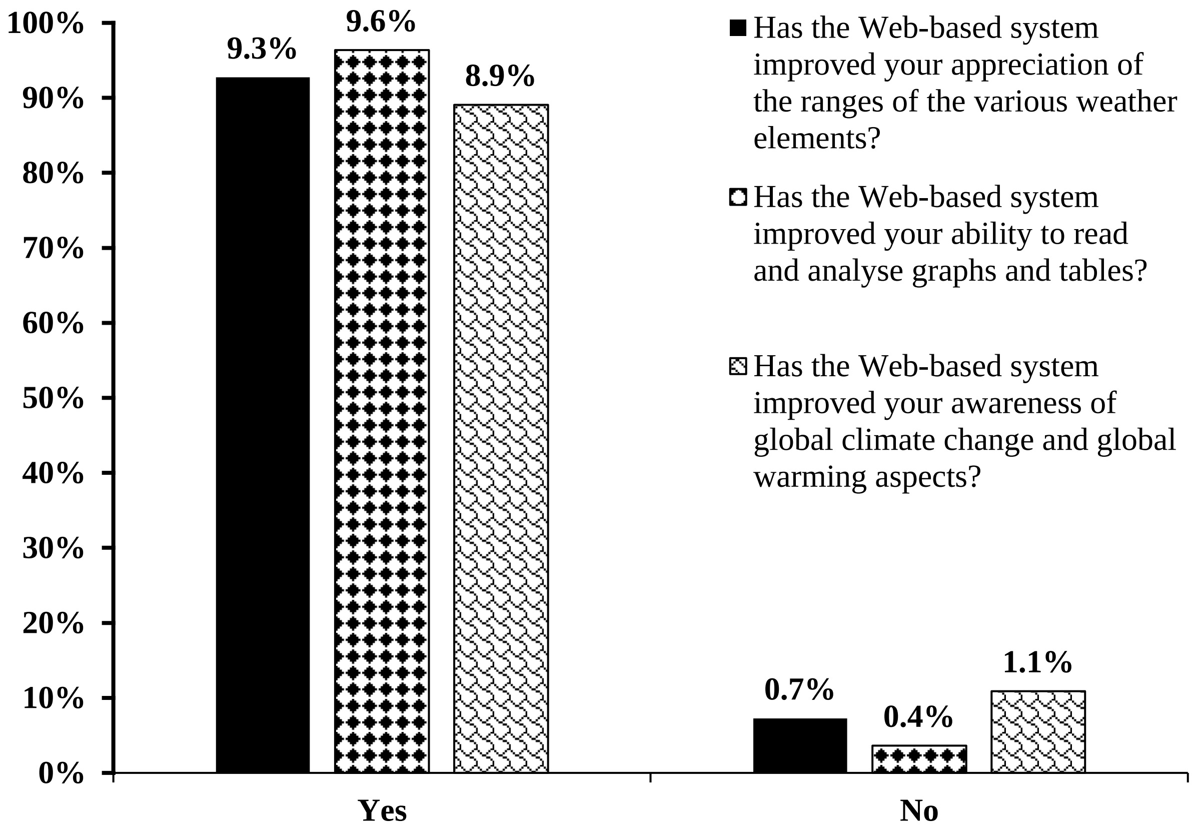


Figure 4.5 Bar graph indicating effectiveness of the web-based system.

The majority of respondents indicated they could apply knowledge obtained from the web-based system to adapt to adverse weather effects. A large percentage of 92.7 % thought they would be able to apply what they had learnt from the system to everyday life. A gratifying 94.5 % recognised that content from the system could be applied to farming and would be able to advise small farmers about micro-adaptation and mitigation strategies (Table 4.7). A significant 54.5 % of the respondents had already used the system for observing a near real-time event.

Table 4.7 Indicators of application of knowledge for adaptation and mitigation of climate change

		Have you used the system for observing any particular near real-time event?		Total
		Yes	No	
Do you think you can apply what you have learnt from the system to everyday life?	Yes	49.1%	43.6%	92.7%
	No	5.5%	1.8%	7.3%
Total		54.5%	45.5%	100.0%
Do you think you can apply what you have learnt from the system to farming at home?	Yes	52.7%	41.8%	94.5%
	No	1.8%	3.6%	5.5%
Total		54.5%	45.5%	100.0%
Would you be able to advise farmers/parents, grandparents, on how to mitigate against bad weather caused by climate change using knowledge from the system?	Yes	49.1%	45.5%	94.5%
	No	5.5%	0.0%	5.5%
Total		54.5%	45.5%	100.0%

4.4.3 Acceptance of web-based system

Prior to the introduction of the web-based system, some 96.4 % indicated that they would like an internet-based service that provided them with current and past weather information. Some 45.5 % are able to access the internet with their mobile phones and do so periodically and 56 % respondents indicated that they have used the system to monitor at least one real-time weather event. A high percentage of 94.5 % claimed they will make use of the system in the future. Table 4.7 finds correlations between different sets of variables which are: interest in internet-based weather service, use of system and desire for future use against scholars' access to the internet.

Table 4.8 Presenting variables that prove the sustainability of the web-based system

		Do you have access to the internet?		Total
		Yes	No	
Would you be interested in an internet-based service that gives you current weather and weather for the previous week?	Yes	43.7 %	52.7 %	96.4 %
	No	1.8 %	1.8 %	3.6 %
Total		45.5 %	54.5 %	100.0 %
Have you used the system for observing any particular near real-time event?	Yes	23.6 %	30.9 %	54.5 %
	No	21.9 %	23.6 %	45.5 %
Total		45.5 %	54.5 %	100.0 %
Would you use the system in the future?	Yes	41.8 %	52.7 %	94.5 %
	No	3.7 %	1.8 %	5.5 %
Total		45.5 %	54.5 %	100.0 %

Some 43.6 % and 52.7 % of the respondents interested in an internet-based weather service have mobile access to internet. A portion of 23.6 % answered 'Yes' both for internet access and using the system for observation of a real-time weather event. The other 30.9 % did not have internet access but were still able to observe an event. The table indicates that access to the internet does not influence desirability of use. A percentage of 41.8 % with internet access indicated they would use the system in the future and 52.7 % without internet access indicated they would be using the system in the future.

CHAPTER 5: DISCUSSION OF RESULTS

5.1 Introduction

This chapter focuses on the interpretation of the results from chapter 4. It discusses the results in relation to the expected results and other relevant studies. Findings obtained in this research are compared and contrasted with others, mainly research that has been conducted on the AIM system. This chapter also makes mention of the limitations of the study because of the significant influence they have on the results.

5.2 Discussion

5.2.1 The web-based system's effect on scholars' learning

The system improved the participants' understanding of environmental concepts. Participants appreciated this method of learning rather than the traditional way and had an overall positive attitude towards the process. These findings correlate with those of Savage (2014) who found the system would had a positive effect on scholars' understanding of terms. It is noted that scientific terms that scholars did not understand the meaning of, were common terms that a natural science scholar is expected and even obliged to understand. Most of these terms exist in the Grade 10, 11 and 12 Geography curriculum. Agriculture (science stream) scholars' understanding of terms and concepts increased because they were presented with a relevant icon or illustration. This reinforces the notion that visualisation transcends language barriers. The display helped improve scholars' grasp of terms supporting Baker's (2015) claim that visualisation helps expand linguistic performance. Atmospheric processes such as ozone depletion were represented with flow diagrams that clearly displayed each feature of the processes, proving that images are effective in aiding comprehension by helping to create associations between known concepts and unfamiliar terms (Baker 2015). Ghaedi and Shahrokhi (2016) compared visualisation and verbalisation teaching methods to learning vocabulary. The study found that the vocabulary of scholars exposed to the visual method of teaching improved because of the perceived attractiveness of this method of learning. Scholars were more motivated and attentive because this method included animation and videos.

Savage (2014) found that the system enhanced scholars' ability to manipulate large datasets into graphs and tables. Scholars demonstrated an improved ability to read and analyse statistical representation of data. This study supports this conclusion. Participants in this study were exposed to line and bar graphs in their disciplines (physical science, mathematics, geography). They are taught by the system to download data from the webpage and export it to Notepad software. In addition, participants learned how to manipulate agro-environmental information using Excel by creating temporal graphs. Downloading data, however, was easier for scholars than copying it to Excel and then creating graphs. With continual use of the system, there is an expectation of improvement.

Through statistical representations of data, scholars learned to find relationships between variables such as soil water potential and soil water content. This indicated they do not think of agro-environmental variables as abstract or independent of each other which consequently makes positive contributions to memory and aids learning. Studies show that learning takes place when our brains make associations/connections between ideas or pieces of information (Heffner 2001). The graphical display improved their appreciation of interactions between different agro-environmental data. Visualisation helped to develop thinking skills, which are higher order skills and are useful for developing problem-solving ability, to ultimately produce a more skilled workforce (Baker 2015; Shatri and Buza 2017).

5.2.2 Results of the baseline study

Most households in Swayimana have access to land and rear livestock. The average size of land for each household is 1.8 ha (Ortmann and King 2007). This is indicative of strategy implementing power that scholars possess. Expressly, scholars from these households are in a better position to practise micro-level agricultural adaptation strategies and/or encourage their parents or guardians to do so be.

The Grade 11 and 12 scholars had a wider variety of sources for climate change information. Mostly, Grade 10 scholars knew about climate change since the topic is included more in the Grade 10 curriculum, and more so in the Geography syllabus. Scholars are introduced to the topic, then progress to the subsequent grades with the knowledge they gained. There was an insignificant difference in the responses indicating differences in perception across grades.

Pitpitunge (2013) found that the information source influenced the scholars' perception of climate change. A comparison of information source and type of information scholars were receiving about climate change was important to note. However, the number of scholars receiving information from sources other than the school was small. Gichuki (2014) found that scholars' and teachers' main information source was the media. Interestingly, the scholars' knowledge of causes and effects of climate change was poor. A possible reason for this is the media's inadequate presentation of climate change due to its complexity (Stamm et al. 2000; Gichuki 2014). Despite this, the scholars who chose media as their information source were more knowledgeable about climate change than those whose information source was school (Gichuki 2014). Anderson (2017) focused specifically on social media and the role it plays in reinforcing perceptions of climate change. Anderson (2017) concluded that it encourages knowledge of climate change, provides space for discussions, framing it as a negative issue as well as connecting climate change activists. However, it also provides opportunity for other social media users to form a sceptical perspective of it (Anderson 2017). This study found the school was the most dominant source but there were scholars who did not understand climate change as a concept and thought it very abstract. This indicates that the traditional way of teaching about climate change in rural schools is not effective.

Harker-Schuch and Bugge-Henriksen (2013) noted effectiveness of the formal teaching and learning environment in acquiring information about scholars' perceptions. They further suggested an urgent need for the improvement of climate change education and noted the deficit in traditional ways of climate change education. The studies done by Gichuki (2014) and Anderson (2017) demonstrates that the layperson learns more about climate change outside of an academic context or a formal teaching and learning environment. This creates vacancy for alternative methods and tools of education for example the AIM system.

5.2.2.1 Perceptions and attitudes of climate change before the AIM system

Most scholars who deemed climate change an important issue, and did not know any practical ways to mitigate and adapt to climate change, had obtained their knowledge from school. These scholars gave textbook answers as to how climate change and variability can be mitigated against because of what causes it. For example, it is commonly known that the burning of fossil fuels is what contributes to climate change. Scholars indicated they refrained from burning fossil fuels, but did not appear to know any products that contain fossil fuels that they avoid burning. Another response that was popular but did not include detail as to how it was accomplished, was ‘reducing air pollution’. It is clear their role in mitigation is not an active one, as it did not involve any behavioural changes. This study supports Pitpitunge (2013) who noted that scholars lacked knowledge more in the area of mitigation and adaptation than they did in basic concepts and causes of climate change. The study done by Pitpitunge (2013) targeted high school and first year scholars. A study by Carr (2015) echoed these results concluded that scholars had a superior understanding of the causes and effects of climate change even though they struggled with the basic concepts. This study however, found that more scholars responded positively concerning adaptation and mitigation. Harker-Schuch and Bugge-Henriksen (2013) and Carr (2015) further noted that there was a misunderstanding of basic concepts and elements of climate change. Scholars confused climate change with ozone depletion and associated it with water pollution, which indicated that they could not distinguish it from other environmental problems.

Scholars understood that climate change is a pressing issue but did not give satisfactory answers as to why they thought it was important. This study confirmed Patchen’s (2010) conclusions that climate change or global warming was a serious problem but was not on the list of their urgent concerns. This study suggests that the scholars’ climate change education and information sources had been effective in communicating alarm but not hope that it can be mitigated and adapted to. Pruneau et al. (2001), as cited by Carr (2015), noted that complacency and helplessness are amongst the reactions that climate change communication produces in individuals. These feelings can be attributed to the use of global images (in traditional methods of climate change communication) that showed melting ice caps and polar bears in climate change education (Anderson 2017). This framed climate change as a distant phenomenon that is unlikely to affect the target audience immediately or in the short to middle term (Wibeck 2013).

5.2.2.2 Impacts of adverse weather

The study investigated the perceived effects of adverse weather related to climate change. Although scholars did not engage in agricultural activities, they noticed the challenges their parents/grandparents had to manage. Farmers are most affected by dry spells, low rainfall and high temperatures. This could be because South Africa experienced an El Niño phase in recent years (2014-2017) and an increase in drought conditions (Makhubu 2015). Global meteorological data reveals that the year 2016 was the hottest year recorded (NASA 2017). An increase in livestock mortality is expected when there is an increase in drought incidence. An increase in plant pests and livestock forage is usually accompanied by high rainfall (IFAD 2009; Enete et al. 2011; Munzhedzi 2013). Climate projections predict increased warmth and drying in subtropical regions (Ayanlade et al. 2017). These highlight the challenges that smallholder farmer’s face and corresponding micro-adaptation strategies that farmers need to be aware of.

Steps to buffer against adverse weather (climate change) have been taken on very few occasions. A climate change effect that was more buffered against, was shifting planting seasons. A coping strategy that was implemented was for farmers to wait for the rains or an indication that they can start planting. This contradicts the first assumptions of the project that the farmers have not adapted to seasonal shifts (UMngeni Resilience Project 2014). Rainfall, rainfall frequency and frost were effects to which they were least adapted. This supports findings by Enete et al. (2011) who suggested that these affects were the most difficult to buffer against because they required greater scientific knowledge and resources. Challenges that hinder adaptation are cost, time constraints, natural resources and labour availability, less infrastructural support and lack of knowledge (Enete et al. 2011; Menike and Arachchi 2016). Overall agricultural adaptation to effects is lacking, which is in line with the assumptions of the study and research.

Scholars have an awareness of climate change as an occurring phenomenon and its significance. However, they were not aware of the roles they could potentially play in agricultural adaptation. Further, their knowledge has not resulted in behavioural changes so they were possibly not aware of their role in mitigation and adaptation. These results confirm the findings of Pruneau et al. (2001), as cited by Carr (2015) that respondents felt powerless and that adaptation/mitigation was someone else’s responsibility. The results of Carr (2015) were more positive, as respondents recognized their potential involvement in combating climate change and had possessed a sense of agency.

5.2.2.3 Scholars’ preference on weather information

Of significance was that scholars were interested in gaining knowledge about solar irradiance as opposed to only minimum and maximum air temperature. Scholars desired to receive more local weather information from their weather service provider. This was confirmation that the AIM system would be perceived as a useful tool even by the community. In addition, this was pleasing since the provision of local weather information is expected to increase community climate change awareness. Several studies found that providing local climate change information creates a positive response from the target audience (Wibeck 2013). The target audience develop concern and are encouraged to be proactive in mitigation.

5.2.3 Assessing the usability, effectiveness and sustainability of the system based on scholars' response

5.2.3.1 Usability of web-based system

Savage (2014) suggested that respondents found interaction with the system easy with a little room for improvement. The web-based system is uncomplicated as scholars were able to alternate between screens and access information about each screen without clicking on it. However, many found it difficult to download data or graphics as a result of their poor computer skills, which is supported by the findings of studies focusing on computer literacy in rural schools. Scholars experienced difficulties with basic activities such as logging in and typing the web address in to access the website. A study by Tire and Mlitwa (2007) noted that poor computer literacy in rural schools in South Africa was prevalent. According to this study, this was due to poor access to ICT or less usage of available ICT tools. Computers were not used because of one or more of these reasons: there were no programs running, few computers compared to number of scholars, and poor computer literacy among educators. This study found that even though computers were available, they were outdated and were not being used because of a lack of relevant curricula. In addition, scholars did not have computers or laptops at home therefore making computer familiarity difficult.

5.2.3.2 Effectiveness of web-based system

The findings of this study prove the assumption that the system improves awareness of differences in weather measurements of various elements, global climate change and global warming aspects. This supports research that claims images and other visuals can influence a person's views about climate change (Munroe 2012). Climate change communication visualisation is usually characterised by images of its effects for example melting ice caps, polar bears, flooding or dry land. This presents climate change as a distant issue that will not affect the target audience immediately. It presents climate change as a non-threatening phenomenon that does not deserve their immediate attention to and influences the layperson's decision to be complacent (Wibeck 2013). It also improves ability to read and analyse graphs and tables. In addition, Savage (2014) found that there was improved ability to display data in graphic/table form and greater awareness of graphics and trends of agro-environmental data.

5.2.3.3 Acceptance of web-based system

The results indicate that scholars have internet access through their smart phones, therefore accessing the website is a possibility. Studies show that the majority of internet users are young, black, are from households that receive less than R1500 a month, and use their phones to access it (O'Hagan 2013). Beger and Sinha 2012 found that 48.9 % of rural youth had internet access compared to 78.6 % of young urban dwellers. Erasmus and Smith (2013) suggested that mobile broadband infrastructure in rural areas was available and provided 3G coverage. However, the situation needs to be improved with more stable broadband services. Another reason for low internet access among rural dwellers according to Beger and Sinha (2012) was concerns for cost. The results indicate that the system is attractive as scholars accessed the website for information outside of school on their mobile phones. Additionally, the limited access to the internet does not necessarily diminish scholars' desire to use the system in the future. Use of the system is sustainable because of the reception it receives from the natural science scholars.

5.3 Suggestions

Savage (2014) highlighted the limitations of software used to create the webpage, and offered suggestions to improve the system. Suggestions by respondents for this study included using more videos. LoggerNet RTMC Pro 4.2 allows the input and display of images and gifs (Graphics Interchange Format) but does not allow the display of videos and animations because of their large size. Although gifs are displayed, CSI Web publisher does not allow them in their animated state. The software displays images clearly but not all images are displayed in their correct position. Some images are dislocated and lost or replaced with another image. Gifs and images display properly when designing the website using RTMC Pro 4.2, on the server, but not on the published website. This could possibly be a result of a computer bandwidth problem and not the software itself. The text, particularly line spacing and text size, can be distorted, which then compromises the overall aesthetics of the entire webpage. Another suggestion was for there to be more quiz-like activities on the website. These can be included, but with limitations. The activities cannot be performed on the website as LoggerNet RTMC Pro 4.2 interactivity is very limited. Some scholars suggested continuing using the system, which would be possible if made more accessible in school. A screen displaying the website could be secured on the corridor.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Overview

Climate change education has proved to be challenging and yet remains a highly recommended strategy towards adapting to climate change. The purpose of the AIM system was to ultimately aid teaching and learning, by overcoming language barriers and other difficulties associated with climate change science communication using visual literacy. In doing so, local/site specific agro-environmental information was provided to the community smallholder farmers. This study used group interviews and two questionnaires to determine the usefulness of the AIM system to the community in the short to medium term. The research project is in agreement with global and national recommendations for climate change adaptation.

There is no other system similar to AIM in South Africa, which serves the purpose of improving science education and disseminating useful agro-environmental information to the community. There is a need for education tools that will complement the traditional ways of teaching and improve academic results for science. Although there are existing web-based educational tools, none are being used in Swayimana High School. The system is based on the discipline of agrometeorology and therefore exposes the high school scholars to science themes, possibly serving as preparation for university.

The youths' perceptions of climate change and adverse weather were consistent with prior literature. School was their main source of climate change information but their understanding was poor. The concept of climate change was abstract and considered relevant only within academic boundaries, and not a global phenomenon that affects them personally. Scholars demonstrate poor knowledge of climate change mitigation and adaptation strategies. It is evident that the youth of Swayimana lack awareness around climate change, which might be the cause of their seeming attitude of indifference.

The AIM system can enhance the community's resilience to climate change by providing near real-time weather data to smallholder farmers and be relevant as an educational tool. It proves to be a suitable tool not only for climate change education but for teaching and learning natural sciences. Mobile phones were used to access the website to observe near real-time events, where the scholars are presented with agro-environmental information such as leaf wetness, soil temperature and soil water content. This finding stated previously, together with scholars indicated eagerness to advise farmers on strategies to mitigate adverse weather after the introduction of the AIM system, proves its suitability.

The AIM system proved to be an excellent tool for education to supplement traditional methods of teaching and learning. The visual aspects of the system made it easier to learn technical and geographical concepts that scholars otherwise find difficult to grasp. Further, the system was exciting and novel to learn from which was indicated by how keen scholars were to be taught using the system. This study's findings are in line with assumptions and previous research on the AIM system. The system is user-friendly, effective and sustainable but requires periodic maintenance, and constant internet bundle top-up for there to be uninterrupted communication over the internet. The system can also host a solar panel, a voltage regulator and battery to provide a constant supply of energy and was unaffected by power outages.

Previous research on the AIM system suggested it was fairly easy to use. Scholars in this study were of the opinion that the system is user-friendly but were at a disadvantage because they were unaccustomed to using a computer. To toggle between screens, download data and manipulate it in to temporal graphs was difficult as a consequence of poor computer skills among the scholars.

6.2 Revisiting the aims and objectives

The AIM system was set up in the community of Swayimana to disseminate agro-environmental data to investigate whether it would be beneficial to their climate change resilience. The intention was to make information easily understood by the layperson. It was anticipated that resilience would begin with improving the knowledge of the scholars regarding climate change and that the knowledge would permeate into the community in the longer-term. This system is the first of its kind in South Africa. There are no documented records of an AWS being installed in a rural school to enhance learning and the community's resilience to climate change.

1) The main objective was to investigate how the web-based system enhances Swayimana High School scholars' learning.

The AWS system was installed and programmed to host extra sensors as well as to directly connect to an existing soil water station. A visually rich website was created with open access at http://agromet.ukzn.ac.za:5355/Swayimane. Icons and images were displayed to represent agrometeorological information that is collected by the AWS system. The website's content encompassed the Grade 10, 11 and 12 natural science curriculae while closely imitating content from the original website used by UKZN for teaching and learning. The scholars' grasp of environmental concepts and interpretation of terms were used to determine the web-based system's effect on learning. This was a reflection of how easy it was to understand the content of the AIM webpage.

2) The second objective was to explore scholars' attitudes towards and perceptions of weather and climate change.

The opinions and perceptions of scholars on climate change were investigated to obtain an understanding of the status quo and the value of the AIM system to the understanding of the scholars and the community. It was important to investigate which information most informed scholars' perceptions of climate change. This also served to examine what information source is more effective for communication or has potential that should be exploited. The aspects of climate change most understood were examined and the perceived impacts of adverse weather were also investigated.

3) The third objective was to investigate the response to the web-based system. The system has the potential to add to the community's capacity to adapt and mitigate against the effects of changes in climate. The intention was to develop the system to be as user-friendly as possible, therefore it was essential to obtain feedback from the scholars using it.

How user-friendly, effective and sustainable the system was, was investigated based on the scholars' response. Scholars judged how easy the system was to use and how easy the content of the website was to understand. The acceptance of the web-based system was determined because of the implications it has for the introduction of the system to the community. Further examined was whether scholars accessed the website of their own accord and their willingness to continue. This revealed whether or not scholars recognised the need for the use of the system.

6.3 Contributions to new knowledge

The AIM system is novel to South Africa as there is no documented evidence of a similar system for the specific purpose of enhancing climate change learning and the community's resilience. Feedback from scholars was positive which suggests that the system would produce improved results if it were used more extensively. A greater number of scholars will experience the benefits of using the system such as grasping the meaning of scientific terms and concepts. The system encourages in-depth learning of natural sciences as it helps link natural science themes. Scholars are able to associate natural science concepts and consequently develop a better understanding of the subject matter. Scholars are able to associate themes and concepts from the website with those they have met previously in their subjects. Additionally, the web-based learning encouraged active participation in lessons. There is a need for more diverse teaching methods, which makes the AIM system deserving of government investment.

Computer literacy is poor in rural schools for both teachers and scholars which presents a challenge for scholars in their future work or academic endeavours. This was indicated in the difficulty scholars experienced switching on computers, navigating to and viewing the AIM website. The scholars however, were willing to access the webpage with their phones. This is an advantage since they find it easier to navigate the website on their mobile phones because they are much more familiar with them. The scholars' poor computer literacy is a cause for concern but does not diminish the usability of the AIM system. It can still be used with a mobile phone but would reach a smaller audience.

Despite studies suggesting youth are not interested in agriculture or topics revolving around climate, this study finds that scholars were willing to share knowledge with their parents/grandparents who are farmers in the community. Even within the scholar community scholars were educating their peers about climate change before the introduction of the AIM system. This indicated they already appreciate the importance of education for addressing environmental problems, therefore an increase in knowledge is an advantage. Further, the AIM system encouraged them to pursue natural sciences in university. The web-based system will aid the community's resilience in the long-term through the new knowledge gained. It will help build the resilience by understanding that climate is changing, and new ways of farming and storing water will be embraced. The web-based system could be expanded to include other themes in the geography, agriculture, mathematics and physical sciences curriculae.

6.4 Research limitations and challenges faced

6.4.1 Internet access at site

There was no internet access at the school during the period of the study, which limited scholars' access to the website. Further, the computers at the school were outdated and were not wi-fi enabled, therefore during lessons scholars had to share computers in groups. Scholars were divided into groups to work with the few computers, which were provided by the URP, with wi-fi capability. This meant that some scholars did not get a turn to use a computer, for toggling between screens, downloading data, and drawing graphs.

6.4.2 Time constraints

The researcher had to work around the timetable or work with scholars during their free lessons. Each class enjoyed only two lessons (during the time of this research) of browsing the website, carrying out the activities and downloading data to draw graphs. Therefore, time to view the website and in turn grasp terms and draw graphs and focus on climate change content was limited and this affected the results.

6.4.3 Sample size

The study was limited to the Swayimana High School where the weather station was installed. The study, therefore, does not represent opinions of scholars in all of the schools in the Swayimana area. The sample was limited to scholars in the science stream (agriculture, life science and physical sciences). The consent limited the number of scholars that were able to participate in the evaluation process. The scholars were allowed to stop at any time (when or if they felt uncomfortable) and this resulted in some incomplete questionnaires. Further, data collection was performed around examination time, and some scholars could not therefore participate fully in the study. All these factors contributed to the smaller sample size than what was initially planned although meaning for results were obtained. A larger sample size ensures a more accurate representation of the population. The smaller sample size reduced the certainty of relationships in the data collected.

6.4.4 Home environment

The home environment and background of the scholars plays an important role in their learning. Home environment encompasses parental structure, involvement, education level and occupation as well as home language. A two-parent home with parental involvement in the scholar’s academics would have a positive influence on learning. Scholars of parents’ who have a higher education level and occupation status learn better than those with parents who spent fewer years in formal schooling (Mdanda 1997; Juan and Visser 2017). Further, scholars are more likely to perform better academically when the language of teaching is their home language. In this study the majority of the scholars came from single-parent households of low socio-economic status.

6.5 Recommendations for future research and conclusion recommendations

6.5.1 Recommendations for future research

Research on the usability of the system should be continued over a longer period of time and in more rural schools, to obtain more accurate results. There are possibly more benefits the system offers for scholars’ education and climate change awareness that are yet to be discovered. Therefore, a study that exposes the scholars to the system for at least a year is necessary. The quarter term agriculture and geography results can be compared to previous years to determine whether the system improves overall science learning. In addition, the project sample should be expanded to increase reliability of results. The research should include a study investigating smallholder farmers’ response to the system, and their attitudes or challenges to using it. Through the course of this research, it was evident that additional research on ICT capacity in rural schools is required. Interventions are required to address the lack of capacity in the field of ICT in school. Future research should focus on teachers and how equipped they are to teach climate change science by ascertaining their perceptions and attitudes. Their lack of perception and poor attitude towards behavioural change in response to climate change may negatively influence scholars.

6.5.2 Recommendations for Government and University of KwaZulu-Natal

a) IT (Information Technology) or computer science should be reincorporated into Swayimana High School's curriculum in order to improve computer literacy. Relevant programmes should be designed for teachers so that they are equipped to teach IT.

b) Climate change education should be incorporated into an agriculture curriculum. Aspects of geography should be included in the agriculture syllabus so that scholars enjoy a more holistic understanding of agriculture and environmental problems.

c) More website-creating software should be explored to create screens that would incorporate videos and quizzes to increase interactivity and enhance learning. Further, the system should be adopted as a tool that geography and agriculture teachers use to supplement their methods of teaching. In addition, an offline version of the AIM system can be used to overcome the challenge of internet access and could be implemented.

d) The AIM system could be expanded to include other themes in the geography and agriculture, mathematics and physical sciences curriculae. It could be developed into an all-round teaching and learning tool and could possibly improve the quality of education for resource-poor rural schools. Teachers should be trained to maintain the system for sustainability of the initiative.

6.6 Final comments and summary conclusions

The study used two questionnaires and group discussions to investigate the response of 55 respondents to the web-based system. The baseline study demonstrated that scholars' perceived adverse weather and climate change an important issue but they were not aware of micro-level adaptation strategies and therefore, were poorly equipped to participate in its adaptation or mitigation. There is a need for more diverse teaching methods of climate change science and natural science in general.

Feedback from scholars on the AIM system was positive and suggested that it would produce better results for their learning if they used the system more extensively. The web-based learning encouraged critical thinking, active participation in lessons and helped improve scholars' computer skills. Scholars improved their grasp on environmental terms and understanding of concepts due to the visual nature of the system. The results indicate that it would be possible for the layperson to grasp the content of the website. More specifically scholars from Grades 10 to 12 and adults that have been exposed to some formal education would be able understand the website. Further, the system improved scholars' ability to read and analyse graphs and tables representing statistical data. Scholars indicated eagerness to continue using the AIM web-based system and suggested ways it can be advanced to further enhance their learning.

The results demonstrated the suitability of the AIM system as a climate change education and weather information tool for Swayimana and other rural communities. The system is user-friendly, effective and can also be programmed to host extra sensors to record agro-environmental data of relevance. The AIM system is feasible to install provided it is maintained and there are funds available for a monthly internet bundle top-up. Another factor that demonstrated its sustainability was the level of acceptance the system received from scholars. Mobile phones were used to access the website to observe near real-time events, where the scholars are presented with agro-environmental information such as leaf wetness, soil temperature and water content. This is agro-environmental information of relevance to the local smallholder farmers, and scholars indicated an eagerness to share the information.

Difficulties with the system use were a consequence of the poor computer literacy skills among the scholars. Programmes should be designed for rural teachers that are focused on improving computer literacy. Internet access was also a challenge, therefore an offline version of the AIM web-based system should be developed. Time constraints, internet access, narrow sample size and scholars' home environment were found to be challenges and limitations to the study. The system should be used over a longer period of time so that the scholars, school and community could enjoy the discovered benefits the system offers. The continual use of the system by the scholars would ensure that the school and community could enjoy the discovered and undiscovered benefits the system offers.

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Appendices

Appendix A: Program used for datalogger

```
' CSA Job: 1770
' Client: UKZN
' Station: ###
' Datalogger: CR3000
' Description:
' Usage:

' Notes:ETo Lat, Lon, Alt must be set to local and hard coded in the
program and re-uploaded.
' Version: 1 Revision: 0 Date: 15.03.2016 Description: Integration & lab
test Author MDT CSA

'-Station ID-----------------------------------------------------------
------------
StationName = ###

'-User settings--------------------------------------------------------
------------
Public Latitude = -29.51896  'Decimal degrees
Public Longitude = 30.69456 'Decimal degrees
Public Altitude = 875  'Metres above sea level

'-Declare Variables and Units-------------------------------------------
------------
'Misc------------------------------------------------------------------
------------
Public BattV

'Modem variables
Dim NowMin
Dim CellCon
Public RTime(9)

'Met-------------------------------------------------------------------
------------
Public PTemp_C
Public WS_ms
Public WindDir
Public AirTC
Public RH
Public Rain_mm
Public SlrW
Public SlrMJ
Public BP_mbar
Public CS65X(6)
Public CS65X_2(6)
Public CS65X_3(6)
Public EvapHour
Public EvapDay
Public LWmV
Public LWMDry
Public LWMCon
Public LWMWet
```

```
Alias CS65X(1)=VWC
Alias CS65X(2)=EC
Alias CS65X(3)=T
Alias CS65X(4)=P
Alias CS65X(5)=PA
Alias CS65X(6)=VR
Alias CS65X_2(1)=VWC_2
Alias CS65X_2(2)=EC_2
Alias CS65X_2(3)=T_2
Alias CS65X_2(4)=P_2
Alias CS65X_2(5)=PA_2
Alias CS65X_2(6)=VR_2
Alias CS65X_3(1)=VWC_3
Alias CS65X_3(2)=EC_3
Alias CS65X_3(3)=T_3
Alias CS65X_3(4)=P_3
Alias CS65X_3(5)=PA_3
Alias CS65X_3(6)=VR_3

Units BattV=Volts
Units PTemp_C=Deg C
Units WS_ms=meters/second
Units WindDir=degrees
Units AirTC=Deg C
Units RH=%
Units Rain_mm=mm
Units SlrW=W/m^2
Units SlrMJ=MJ/m^2
Units BP_mbar=mbar
Units ETos = mm
Units Rso = MJ/m^2
Units EvapHour = mm
Units EvapDay = mm
Units LWmV=mV
Units LWMDry=Minutes
Units LWMCon=Minutes
Units LWMWet=Minutes
Units VWC=m^3/m^3
Units EC=dS/m
Units T=Deg C
Units P=unitless
Units PA=nSec
Units VR=unitless
Units VWC_2=m^3/m^3
Units EC_2=dS/m
Units T_2=Deg C
Units P_2=unitless
Units PA_2=nSec
Units VR_2=unitless
Units VWC_3=m^3/m^3
Units EC_3=dS/m
Units T_3=Deg C
Units P_3=unitless
Units PA_3=nSec
Units VR_3=unitless

'Define Data Tables----------------------------------------------------------
------------
DataTable(TableETTempHour, true,-1)  'Temporary table to calculate ET
before calling the final hourly table
```

```
  TableHide
DataInterval(0,60,Min,10)
  ETsz (AirTC,RH,WS_ms,SlrMJ,Longitude,Latitude,Altitude,3,0,FP2,False)
FieldNames("ETos,Rso")
EndTable

DataTable(TableETTempDay, true,-1)  'Temporary table to calculate ET before
calling the final hourly table
  TableHide
DataInterval(0,1440,Min,10)
  ETsz (AirTC,RH,WS_ms,SlrMJ,Longitude,Latitude,Altitude,3,0,FP2,False)
FieldNames("ETos,Rso")
EndTable

DataTable(TableMetEvapHour,True,-1)
DataInterval(0,60,Min,10)
Sample(1,Status.StationName,String)
Average(1,BattV,fp2,false)
WindVector(1,WS_ms,WindDir,FP2,False,0,0,0)
FieldNames("WS_ms_S_WVT,WindDir_D1_WVT,WindDir_SD1_WVT")
Maximum(1,WS_ms,FP2,False,False)
Average(1,AirTC,FP2,False)
Sample(1,RH,FP2)
Totalize(1,Rain_mm,FP2,False)
Average(1,SlrW,FP2,False)
Totalize(1,SlrMJ,IEEE4,False)
Average(1,BP_mbar,FP2,False)
  ETsz (AirTC,RH,WS_ms,SlrMJ,Longitude,Latitude,Altitude,3,0,FP2,False)
FieldNames("ETos,Rso")
Sample(1,EvapHour,FP2)
Average(1,VWC,FP2,False)
Average(1,EC,FP2,False)
Average(1,T,FP2,False)
Average(1,P,FP2,False)
Average(1,PA,FP2,False)
Average(1,VR,FP2,False)
Average(1,VWC_2,FP2,False)
Average(1,EC_2,FP2,False)
Average(1,T_2,FP2,False)
Average(1,P_2,FP2,False)
Average(1,PA_2,FP2,False)
Average(1,VR_2,FP2,False)
Average(1,VWC_3,FP2,False)
Average(1,EC_3,FP2,False)
Average(1,T_3,FP2,False)
Average(1,P_3,FP2,False)
Average(1,PA_3,FP2,False)
Average(1,VR_3,FP2,False)
Average(1,LWmV,FP2,False)
Totalize(1,LWMDry,FP2,False)
Totalize(1,LWMCon,FP2,False)
Totalize(1,LWMWet,FP2,False)
EndTable

DataTable(TableMetEvap2min,True,-1)
DataInterval(0,2,Min,10)
Sample(1,Status.StationName,String)
Average(1,BattV,fp2,false)
WindVector(1,WS_ms,WindDir,FP2,False,0,0,0)
FieldNames("WS_ms_S_WVT,WindDir_D1_WVT,WindDir_SD1_WVT")
Maximum(1,WS_ms,FP2,False,False)
```

```
Average(1,AirTC,FP2,False)
Sample(1,RH,FP2)
Totalize(1,Rain_mm,FP2,False)
Average(1,SlrW,FP2,False)
Totalize(1,SlrMJ,IEEE4,False)
Average(1,BP_mbar,FP2,False)
'Sample(1,VWC,FP2)
'Sample(1,EC,FP2)
'Sample(1,T,FP2)
'Sample(1,P,FP2)
'Sample(1,PA,FP2)
'Sample(1,VR,FP2)
'Sample(1,VWC_2,FP2)
'Sample(1,EC_2,FP2)
'Sample(1,T_2,FP2)
'Sample(1,P_2,FP2)
'Sample(1,PA_2,FP2)
'Sample(1,VR_2,FP2)
'Sample(1,VWC_3,FP2)
'Sample(1,EC_3,FP2)
'Sample(1,T_3,FP2)
'Sample(1,P_3,FP2)
'Sample(1,PA_3,FP2)
'Sample(1,VR_3,FP2)
Average(1,LWmV,FP2,False)
Totalize(1,LWMDry,FP2,False)
Totalize(1,LWMCon,FP2,False)
Totalize(1,LWMWet,FP2,False)
EndTable

DataTable(TableMetEvapDay,True,-1)
DataInterval(0,1440,Min,10)
Sample(1,Status.StationName,String)
Average(1,BattV,fp2,false)
WindVector(1,WS_ms,WindDir,FP2,False,0,0,0)
FieldNames("WS_ms_S_WVT,WindDir_D1_WVT,WindDir_SD1_WVT")
Maximum(1,WS_ms,FP2,False,False)
Maximum(1,AirTC,FP2,False,False)
Minimum(1,AirTC,FP2,False,False)
Maximum(1,RH,FP2,False,False)
Minimum(1,RH,FP2,False,False)
Totalize(1,Rain_mm,FP2,False)
Maximum(1,SlrW,FP2,False,False)
Totalize(1,SlrMJ,IEEE4,False)
Maximum(1,BP_mbar,FP2,False,False)
Minimum(1,BP_mbar,FP2,False,False)
  ETsz (AirTC,RH,WS_ms,SlrMJ,Longitude,Latitude,Altitude,3,0,FP2,False)
FieldNames("ETos,Rso")
Sample(1,EvapDay,FP2)
Average(1,VWC,FP2,False)
Average(1,EC,FP2,False)
Average(1,T,FP2,False)
Average(1,P,FP2,False)
Average(1,PA,FP2,False)
Average(1,VR,FP2,False)
Average(1,VWC_2,FP2,False)
Average(1,EC_2,FP2,False)
Average(1,T_2,FP2,False)
Average(1,P_2,FP2,False)
Average(1,PA_2,FP2,False)
Average(1,VR_2,FP2,False)
```

```
Average(1,VWC_3,FP2,False)
Average(1,EC_3,FP2,False)
Average(1,T_3,FP2,False)
Average(1,P_3,FP2,False)
Average(1,PA_3,FP2,False)
Average(1,VR_3,FP2,False)
Maximum(1,VWC,FP2,False,False)
Maximum(1,EC,FP2,False,False)
Maximum(1,T,FP2,False,False)
Maximum(1,P,FP2,False,False)
Maximum(1,PA,FP2,False,False)
Maximum(1,VR,FP2,False,False)
Maximum(1,VWC_2,FP2,False,False)
Maximum(1,EC_2,FP2,False,False)
Maximum(1,T_2,FP2,False,False)
Maximum(1,P_2,FP2,False,False)
Maximum(1,PA_2,FP2,False,False)
Maximum(1,VR_2,FP2,False,False)
Maximum(1,VWC_3,FP2,False,False)
Maximum(1,EC_3,FP2,False,False)
Maximum(1,T_3,FP2,False,False)
Maximum(1,P_3,FP2,False,False)
Maximum(1,PA_3,FP2,False,False)
Maximum(1,VR_3,FP2,False,False)
Minimum(1,VWC,FP2,False,False)
Minimum(1,EC,FP2,False,False)
Minimum(1,T,FP2,False,False)
Minimum(1,P,FP2,False,False)
Minimum(1,PA,FP2,False,False)
Minimum(1,VR,FP2,False,False)
Minimum(1,VWC_2,FP2,False,False)
Minimum(1,EC_2,FP2,False,False)
Minimum(1,T_2,FP2,False,False)
Minimum(1,P_2,FP2,False,False)
Minimum(1,PA_2,FP2,False,False)
Minimum(1,VR_2,FP2,False,False)
Minimum(1,VWC_3,FP2,False,False)
Minimum(1,EC_3,FP2,False,False)
Minimum(1,T_3,FP2,False,False)
Minimum(1,P_3,FP2,False,False)
Minimum(1,PA_3,FP2,False,False)
Minimum(1,VR_3,FP2,False,False)
Average(1,LWmV,FP2,False)
Totalize(1,LWMDry,FP2,False)
Totalize(1,LWMCon,FP2,False)
Totalize(1,LWMWet,FP2,False)
EndTable

DataTable(Diagnostics,True,365)
DataInterval(0,1440,Min,0)
Sample(1,Status.StationName,String)
Maximum(1,BattV,FP2,False,False)
Minimum(1,BattV,FP2,False,False)
Maximum(1,PTemp_C,FP2,False,False)
Minimum(1,PTemp_C,FP2,False,False
Sample(1,Status.OSVersion,String)
Sample(1,Status.SerialNumber,IEEE4)
Sample(1,Status.StartTime,IEEE4)
Sample(1,Status.RunSignature,IEEE4)
Sample(1,Status.ProgSignature,IEEE4)
Sample(1,Status.LithiumBattery,IEEE4)
```

```
Sample(1,Status.Low12VCount,IEEE4)
Sample(1,Status.SkippedScan,IEEE4)
Sample(1,Status.CPUDriveFree,IEEE4)
Sample(1,Status.USRDriveFree,IEEE4)
EndTable

'-Main Program----------------------------------------------------------
------------
BeginProg
  '--Main Scan
Scan(5,Sec,1,0) 'Must be 5s (SlrMJ calculation is based on 5s)

    'Default Datalogger Battery Voltage measurement 'BattV'
Battery(BattV)

    'Default Wiring Panel Temperature measurement 'PTemp_C'
PanelTemp(PTemp_C,_50Hz)

    '05103 Wind Speed & Direction Sensor measurements 'WS_ms' and 'WindDir'
PulseCount(WS_ms,1,1,1,1,0.098,0)
    BrHalf(WindDir,1,mV5000,1,1,1,5000,True,0,_50Hz,355,0)
    If WindDir>=360 OR WindDir<0 Then WindDir=0

    'HC2S3 (constant power) Temperature & Relative Humidity Sensor
measurements 'AirTC' and 'RH'
VoltSe(AirTC,1,mV1000,2,0,0,_50Hz,0.1,-40)
VoltSe(RH,1,mV1000,3,0,0,_50Hz,0.1,0)
    If RH>100 AND RH<103 Then RH=100

    'TR525I Rain Gauge Measurement 0.2mm Tip 'Rain_mm'
PulseCount(Rain_mm,1,2,2,0,0.2,0)

    'LI200X Pyranometer measurements 'SlrMJ' and 'SlrW'
VoltDiff(SlrW,1,mV20,3,True,0,_50Hz,1,0)
    If SlrW<0 Then SlrW=0
    SlrMJ=SlrW*0.001
    '       Was SlrMJ=SlrW*0.0002
    SlrW=SlrW*200

    'CS106 Barometric Pressure Sensor measurement 'BP_mbar'
PortSet(1,1)
VoltSe(BP_mbar,1,mV5000,4,1,0,_50Hz,0.240,500)

    'CS650/655 Water Content Reflectometer measurements 'VWC', 'EC', and
'T'
    If TimeIntoInterval(0,1,Hr) Then
SDI12Recorder(CS65X(),3,"0","M3!",1,0)
    EndIf
    'CS650/655 Water Content Reflectometer measurements 'VWC_2', 'EC_2',
and 'T_2'
    If TimeIntoInterval(0,1,Hr) Then
SDI12Recorder(CS65X_2(),3,"1","M3!",1,0)
    EndIf
    'CS650/655 Water Content Reflectometer measurements 'VWC_3', 'EC_3',
and 'T_3'
    If TimeIntoInterval(0,1,Hr) Then
SDI12Recorder(CS65X_3(),3,"2","M3!",1,0)
    EndIf
    'LWS Dielectric Leaf Wetness Sensor measurement 'LWmV'
    BrHalf(LWmV,1,mV5000,7,1,1,2500,False,10000,_50Hz,2500,0)
```

```
    'Determine Minutes Dry 'LWMDry', Minutes Wet or Contaminated 'LWMCon',
and Minutes Wet 'LWMWet' for this Scan
    LWMDry=0
    LWMCon=0
    LWMWet=0
    If LWmV<274 Then
      LWMDry=0.08333333
    Else
      If LWmV>=284 Then
        LWMWet=0.08333333
      Else
        LWMCon=0.08333333
      EndIf
    EndIf
    'Calculate Evap from ETo - Must be done before calling TableMetEvapHour
    'So the logger could get ETo and then in a spreadsheet these values
could be multiplied by 1.10. This is best done using daily ETo, not hourly
ETo.
    CallTable TableETTempHour
    EvapHour = TableETTempHour.ETos(1,1) * 1.1
    CallTable TableETTempDay
    EvapDay = TableETTempDay.ETos(1,1) * 1.1

    'Cellular Phone Control
    'Turn the cell phone on for 3 minutes every 60 minutes between 0 and
2359 hours.
RealTime(RTime(1))
    '1=year, 2=month, 3=day of month, 4=hour of day, 5=minutes,
    '6=seconds, 7=microseconds, 8=day of week, 9=day of year
    NowMin=RTime(4)*60+RTime(5)
    'If NowMin>=0 AND NowMin<1439 AND (NowMin-0) MOD 60<10 Then
      CellCon=1
    'Else
      'CellCon=0
    'EndIf
    If BattV<11 OR NowMin MOD 60>58 Then
      CellCon=0
    EndIf

    If CellCon=1 Then
      SW12 (1,1 )
    Else
      SW12 (1,0)
    EndIf

    'Call Data Tables and Store Data
    CallTable TableMetEvap2min
    CallTable TableMetEvapHour
    CallTable TableMetEvapDay
    CallTable Diagnostics

  NextScan
EndProg
```

Appendix B: Automatic weather station system with additional instruments and serial connection to pre-existing soil water station (the automatic weather station taken at Swayimana High School in August 2017). Photo: ZibuyileDlamini.

Appendix C: Letter of declaration of consent

UNIVERSITY OF KWAZULU-NATAL

COLLEGE OF AGRICULTURE, ENGINEERING AND SCIENCE

Researcher: Miss Zibuyile Dlamini (0766132071)
Supervisor: Prof. Michael Savage (0332605514)
Research Office: Prem Mohun, Research Office: Ethics, Westville Campus (031 260 4557) email mohunp@ukzn.ac.za

Dear Respondent

I, **Zibuyile Dlamini,** a Master of Sciencescholar, at the **College of Agriculture, Engineering and Science**, of the University of KwaZulu-Natal invite you to participate in a research project entitled "Testing and evaluation of a newly installed Agrometeorology Instrumentation Mast (AIM) Web-based system in a rural school in Swayimana'' The aim of this study is to determine how the Web based system can enhance the community of Swayimana's resilience to climate change.

Through your participation I hope to address the following questions:

- Perceptions weather and climate change.
- Identify new concepts learnt from the Web based system.
- Determine the usability of the Web based system.

Your participation in this project is voluntary. You may refuse to participate or withdraw from the project at any time with no negative consequence. There will be no monetary gain from participating in this survey. Confidentiality and anonymity of records identifying you as a participant will be maintained by theCollege of Agriculture, Engineering and Science, UKZN.

If you have any questions or concerns about participating in this study, you may contact me or my supervisor on the numbers listed above.

The questionnaire should take you about **20-30** minutes to complete.

Sincerely

Researcher's Signature_________________ Date_________________

CONSENT

I …………………………………………………………………………… (Full names & surname of participant) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project.

I understand that I am at liberty to withdraw from the project at any time, should I so desire.

I hereby consent to allowing this interview to be tape recorded Yes ☐ No ☐

Signature of Participant…...……………… Date……………………..

Appendix D: Questionnaire 1 (used to obtain baseline data)

University of KwaZulu-Natal

Questionnaire

All the information provided here will be treated as **STRICTLY CONFIDENTIAL**

Name: ………………………………………………………………………………………

Grade: ………………………………………………………………………………………

Gender: Male ☐ Female ☐

Section A

1. Do you have access to the internet/ Unayo i internet?

   Yes/Yebo ☐No/Cha ☐

   a. If yes, how often do you use it? Uyisebenzisa kangakanani

____

2. Do you have land at home that your family farms/ Ninawo umhlaba entshala khona ekhaya?

   Yes/Yebo ☐No/Cha ☐

a. If yes, what crops do you plant/ Iziphi izitshalo enizitshalayo?

____

3. Do you keep livestock/ Ingabe ninayo imfuyo?

Yes/Yebo ☐No/Cha ☐

a. If yes, what livestock do you keep/ Iyiphi imfuyo eninayo ?

____

4. Do you know about climate change/ Ingabe uyazi ngokuguquka kwesimo sezulu?

Yes/Yebo ☐No/Cha ☐

a. If yes, what do you understand about climate change? Waziningayo?

____
____
____
____

5. Where did you get information about climate change from/ Uzwekuphi?

School ☐ Television ☐Newspaper ☐ Radio ☐ Books ☐Internet ☐Other ☐

6. How do you use your knowledge about climate change in everyday life/ Ulusebenzisa kanjani ulwazi lakho

____
____
____
____

7. How important is the issue of climate change to you personally/ Lubaluleke kangakanani udaba lokuguquguquka kwesimo sezulu kuwe?

Very important/Kubaluleke kakhulu ☐ Quite important/ Libaluleke impela ☐

Not very important/ Alibalulekile kakhulu ☐ No at all important/Alibalulekile ☐

a. Why is it important to you/Kungani kubalulekile kuwe?

____
____

____

____

8. Where do you usually get your weather information from? Imininingwane ngesimo sezulu usithathelaphi

   Newspaper ☐ Television ☐ Internet ☐ Radio ☐

9. Would you be interested in an internet-based service that gives you current weather and weather for the previous week? Ubungayithokozela i internet sevisi esekelwe ekunikeza isimo sezulu samanje kanye nesimo esedlule

   Yes/ Yebo ☐No/ Cha ☐

10. What aspects of weather are you usually interested in/ Uyayubheke ini kwisimo sezulu (you may tick more than one/ Unga khetha engaphezu kweyodwa)?

    Maximum temperature ☐ Minimum temperature ☐Rain ☐ Wind speed ☐ Cloud ☐ Sunshine ☐

    Frost ☐ Berg winds ☐

11. Which of the following weather aspects shape your day to day decisions? Yisiphi isici esisodwa sezulu eziba nomthelela kwizinqumo zakho nsuku nansuku

    Maximum temperature ☐ Minimum temperature ☐ Rain ☐ Wind speed ☐ Cloud ☐ Sunshine ☐

12. Are there any things you want from weather services that you do not usually get/ Zikhona izinto ozifunayo kwi weather service ongaytholi? What are these/ Ziyini
    (You can choose more than one/ Unga khetha engaphezu kweyodwa)

    More local information ☐ Clearer symbols ☐ Detailed information☐

    Pollution indicator ☐ Sunburn warnings ☐

Section B

1. What challenges have you noticed your parents/grandparents encounter in farming/Iziphi izinkinga uke wezwa abazalinoma ogogo nomkhulu ukuthi bahlangana nazo ekulimeni?

a. what have you noticed (with respect to the list below/ Kulokhu okungezansi)/ Uboneni

	Increase	Decrease	Steps taken to reduce negative effects	I have not noticed any challenge
Rainfall/ Imvula				
Rainfall frequency				
Temperature/ Ukushisa				
Frost/Isithwathwa				
Dry spells/Isomiso				
Soil erosion/Ukuguguleka komhlaba				
Soil moisture/ Ukuswakama komhlaba				
Shifting planting seasons/Ukushintsha kwezikhathi zonyaka				
Changes in plant growth/ Inguquko ekukhuleni kwezitshalo				
Plant pests/ Izinambuzane ezitshalweni				
Plant diseases /Izifo ezitshalweni				
Livestock forage/Ukudla kwemfuyo				
Livestock diseases/Izifo kwimfuyo				
Livestock pests/ Izinambuzane kwimfuyo				
Livestock mortality/Ukufa kwemfuyo				
Other/Okunye				

2. Are you able to read values such a maximum and minimum values off graphs/Uyakwazi ukufunda ama max and min kwigraph?

   Yes/ Yebo ☐ No/ Cha ☐

3. Are you able to interpret line graphs/ Uyakwazi ukufunda ama line graph?

   Yes/ Yebo ☐ No/ Cha ☐

4. Do you understand any of these following terms/ Uyazazi ukuthi zisho ukuthini lezinto

   Solar irradiance ☐ Wind speed and direction ☐Dew point temperature ☐

   Air temperature ☐Relative humidity ☐ Berg wind ☐ Heat index ☐

5. Would you be interested in weather forecasting/ Ubungeke uthokozele ukubikezela isimo sezulu?

   Yes/ Yebo ☐No/ Cha ☐

Appendix E: Questionnaire 2

University of KwaZulu-Natal

Questionnaire

All the information provided here will be treated as **STRICTLY CONFIDENTIAL**

Name: ………………………………………………………………………………………

Grade: ………………………………………………………………………………………

Gender: Male ☐ Female ☐

You were shown one or more of the live date screens/ Uboniswe eyodwa noma ngaphezulu izikrini zosuku olubukhoma

1. Do you understand any of these following terms/ Uyazazi ukuthi zisho ukuthini lezinto

   Solar irradiance ☐ Wind speed and direction ☐Soil water potential ☐

   Air temperature ☐Relative humidity ☐ Berg wind ☐ Heat index ☐

2. What other terms have you learnt/ imaphi amagama owafundile futhi?

   ____

   ____

3. Is the understanding due to the newly installed AIM system/Ulwazi lakho lungenxa ya loluhlelo olusha?

Yes/ Yebo ☐ No/ Cha ☐

4. Did you understand most of what was displayed/Ubuwazi lokhu kade ukubhekile?

Yes/ Yebo ☐ No/ Cha ☐

a. What do you like the most/Uthande ini kakhulu?

b. What did you like the least/Uthande ini kancane?

5. Do you think the display helped your understanding of weather and weather events irrespective of language/ Ucabanga ukuthi isibonisi sikusizile ekuqondeni isimo sezulu nezenzakalo zezulu ngaphandle kokubheka ulimi? Please elaborate/awuke uchaze?

Yes/ Yebo ☐ No/ Cha ☐

b. How easy was it to use/Bekulula kangakanani?

____

c. How can it be made simpler/ Ingabe kukhona okungafakwa kuhlelo okungaholela ukuth kube lula ngaphambilini? Please elaborate/ awuke uchaze?

____
____
____
____

6. Have you used the system for observing any particular near real-time event(s)/Usuke wausebenzisa ukubheka isenzakalo sezulu?

Yes/ Yebo ☐ No/ Cha ☐

7. Is the content of the system related to the content of subjects you are doing/ Ingabe kukhona okuleluhlelo oluhlobene nezimfundo ozenzayo?

Yes/ Yebo ☐ No/ Cha ☐

a. Which screens are most relevant to your subjects/ Iziphi izikrini ezihambelana kakhulu nezihloko zakho

____

8. Do you think the content in the subjects would be easier to understand if they were taught in this way instead of in the classroom/ Ucabanga ukuthi izimfundo zakho zingaba lula ukuqonda uma befundiswa ngale ndlela esikhundleni seklasini?

Yes/ Yebo ☐ No/ Cha ☐

a. Why do you think so/Yinindaba ucabanga kanje?

____
____
____
____

9. Have you ever downloaded data or graphics from the system/ Wake wadownload idatha noma ihluzo kusuka ohlelweni?

Yes/ Yebo ☐ No/ Cha ☐

a. How easy was it to do/Bekulula kangakanani? Please elaborate/ awuke uchaze?

____
____
____
____

Has the Web-based system improved your appreciation of the ranges of the various weather elements/ Ingabe uhlelo ikusizile zathuthukisa ukulazisa kwakho amabanga izakhi ezahlukene sezulu?

Yes/ Yebo ☐ No/ Cha ☐

____
____

10. Has the Web-based system improved your ability to read and analyse graphs and tables/ Ingabe uhlelo lukusizile ekuthuthukiseni ikhono lakho lokufunda futhi ahlaziye amagrafu namathebula.

Yes/ Yebo ☐ No/ Cha ☐

11. Has the Web-based system improved your awareness of global climate change and global warming aspects/ Ingabe uhlelo Web-based ikuthuthukisisile ulwazi lwakho ngokuguquka kwesimo sezulu nokufudumala kwomhlaba?

Yes/ Yebo ☐ No/ Cha ☐

a. If yes, how/ kanjani?

____
____
____
____

12. Do you think you can apply what you have learnt from the system to farming at home/ Ingabe ucabanga ukuthi ungakwazi ukusebenzisa lokho okufundile ohlelweni engadini ekhaya?

Yes/ Yebo ☐ No/ Cha ☐

b. If yes, how/ kanjani?

____
____
____
____

13. Would you be able to advise farmers/parents, grandparents, on how to mitigate against bad weather caused by climate change using knowledge from the system / Ubungeke ukwazi ukweluleka abalimi, usebenzisa ulwazi olitholile kuhlelo? Please elaborate/ awuke uchaze?

____
____
____
____

14. What aspects of the system are most relevant to agriculture/ Iziphi izici (ohlelweni) ezisiza kwezolimo?

15. Do you think you can apply what you have learnt from the system to everyday life/ Ingabe ucabanga ukuthi ungakwazi ukusebenzisa lokho okufundile ohlelweni empilweni yansuku zonke?

Yes/ Yebo ☐ No/ Cha ☐

16. Do you have any suggestion to improve the system/ Ingabe unayo noma yini esikisela ukuba ngcono uhlelo?

Yes/ Yebo ☐ No/ Cha ☐

17. Besides teaching you about climate change how else has the system helped you/ Ngabe uhlelo lukusize ngayiphi indlela?

What else have you learnt/ Ini okusha okufundile?

18. Would you use the system in the future/ Ungaphinde uyisebenzise futhi?

Yes/ Yebo ☐ No/ Cha ☐

19. Please add further comments relevant to this questionnaire/ Sicela ungeze amazwana eminye kuleli lwemibuzo?

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20. Would you be interested in studying Agrometeorology or any climate related science as a subject in university/Ungathanda ukufunda iAgrometeorology noma esinye isifundo esihlangene ne simo sezulu e Univesi?

Yes/ Yebo ☐ No/ Cha ☐

Ngobani

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Appendix F: Group interview guide

1) What did you learn?
2) What screen interests you the most? What is it about the screen that makes it more interesting?
3) Which screen did you understand better?
4) What new terms have you learnt from the system?
5) Did you learn anything new from the system?
6) Do you think your subjects would be easier to understand if they were taught in this way instead of in the classroom?
7) Do you think climate change is something that can be addressed?

Appendix G: Selected answers by selected respondents indicating attitudes

Table 4.4 Indicating attitude towards climate change grouped according to perceived importance

How is the issue of climate change important to you personally? Why is it important to you?	
Importance	**Direct quotes**
Very important	• "because it tells me about the changing of the earth" • "the air we breathe gets damaged" • "so that we have knowledge " • "Yes. It is important because there are crops that need the sun and others that need rain" • "so that we can find the right plants" • "It is important to me because cc determines the temperature of the day that whether it is hot or cold or warm or it is rainy day" • "Because I need sun sometimes I need cold in my body" • "Because there are many issue that are caused by cc especially in human like if there is no rain the plants cannot grow and the animals will die because there is not enough water" • "It is important for me because changes of climate make food that plant to grow healthy" • "you need to know about the weather and it's important to know for your benefits if you made plans to know what the weather is like" • "Because I usually planting the crops with my grandparents" • "So that can see how can I contribute to stop it to have more damage" • "It is important because if the cc is not change our plant they not growing very well" • "Is important" • "It teaches me about what happening around the world I'm living in" • "It due to that it also affects me and the economy of the country" • "To know about cc or weather it helps us to know about changes" • "Because it teaches us more thing about it" • "Because I also live in this earth when there are high rain fall and temperature that might cause death and global warming there will be organism" • "because it shows us if it's time to plant" • "Important to know how the weather changes and what are the effect or that weather" • "that I know the changing of the earth or climate • "it's important because it gives me knowledge about the weather" • "Because we need to know what to wear" • "It is important because it help grandmothers or grandfather it the garden cause they plant different crops that need different weather"

	• "Because I will carry on doing life science subject as I will be doing a forensic science" • "To know the challenges that you may face about the temperatures whether you expect cold or hot" • "Because it can shape my day to day decision in such a way that it can stop me on what I planned for the day" • "It helps to understand more about what happening in the climate • "To know the effect and causes and solutions of climate change" • "To know more about what is happening on the earth" • "To know how will the phase with the changes because some people were not comfortable with sunlight" • "The most of animals are need different season that way its important" • "Some animals cannot survive the extreme temperatures so they died and climate change cause soil erosion" • "It affects humans in terms of changing the weather, it also affects animals and vegetation also get infected by climate change" • "In order to prevent climate change" • "It affect our agriculture and it makes us fall easily" • "it helps us know and plan what to wear the next day and if we will be travelling somewhere"
Quite important	• "it's not important" • "as time goes on the livestock and crops won't be able to grow nicely" • "It because it help us to know when to plant and when to not" • "Because you will know what to crop during which season because we do not have green house in this environment and we can't afford them because we are small farmers" • "Climate change it very important because our land where we plant our crops and when it raining it help our crops for irrigation" • "It because a person need a normal temperature so if the cc decreases or increases you have to know what happened and what changes you overcome even on animals" • "Because everything the need to make sure we don't damage the ozone layer because it will damage our soil while they is much rainfall" • "To trace climate change in our everyday lives"
Not very important	• "it's important to me because my body needs sunshine and a little bit of rain"
Not at all important	• "Plants needs different temperatures"

Appendix H: Consent of gatekeepers (Principal of Swayimana High School and Dean and Head of School of Agricultural, Earth and Environmental Sciences-UKZN)

Declaration of Consent: **Testing and evaluation of a newly installed Agrometeorology Instrumentation Mast (AIM) system in a rural school in Swayimana**

I ...D.M. Lombethe............ (Full names) hereby confirm that I understand the contents of this document and the nature of the research project. I understand that the project involves the utilization of space, existing facilities, surveys and questionnaires.

I consent to the participation of students in the research project.

Signature of Principal: ____________

Date: 06.12.2016

Declaration of Consent: Testing and evaluation of a newly installed Agrometeorology Instrumentation Mast (AIM) system in a rural school in Swayimane.

I..Albert T. Modi.................. (full names of respondent) hereby confirm that I understand the nature of the research project that will be conducted in Swayimane by UKZN student Zibuyile Dlamini.

I confirm my approval of the project.

Signature of Head of School____________

Date 12-09-2016

Appendix I: UKZN ethical clearance letter

UNIVERSITY OF KWAZULU-NATAL™
INYUVESI YAKWAZULU-NATALI

5 January 2017

Miss Zibuyile Dlamini 212520847
School of Agriculture, Earth and Environmental Sciences
Pietermzritzburg Campus

Dear Miss Dlamini

Protocol reference number: HSS/1866/016M
Project title: Testing and evaluation of a newly installed Agrometeoloy Instrumentation Mast (AIM) web-based system in a rural school in Swayimana

Full Approval – Expedited Application

In response to your application received 31 October 2016, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol has been granted **FULL APPROVAL.**

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment /modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

....

Dr Shenuka Singh (Chair)
Humanitities & Social Scinces Research Ethics Committee

/pm

Cc. Supervisor: Professor MJ Savage
Cc. Academic Leader: Professor Onisimo Mutanga
Cc. School Administrator: Ms Marsha Manjoo

Humanities & Social Sciences Research Ethics Committee
Dr Shenuka Singh (Chair)
Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban 4000
Telephone: +27 (0) 31 260 3587/8350/4557 **Facsimile:** +27 (0) 31 260 4609 **Email:** ximbap@ukzn.ac.za / snymanm@ukzn.ac.za / mohunp@ukzn.ac.za
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