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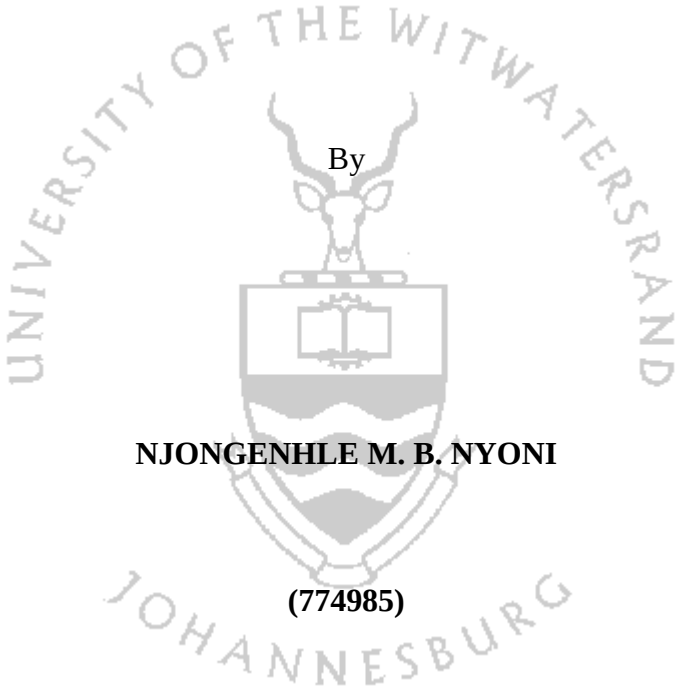
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ESTABLISHING THE IMPACT OF CLIMATE WARMING ON RURAL POULTRY FARMING IN SOUTH AFRICA: A CASE OF LIMPOPO PROVINCE



By

NJONGENHLE M. B. NYONI

(774985)

A thesis submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Supervisors:

Prof. Stefan Grab

Dr. Emma Archer

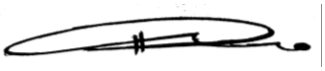
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DECLARATION

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ABSTRACT

Rural households in many developing countries face multiple challenges, including a lack of resources, food insecurity and poverty. Climate change threatens to compound existing challenges. Small-holder farming is particularly vulnerable to climate change due to its limited adaptive capacity. Livestock production is an integral part of the rural agricultural economy, and compared to other livestock types, poultry is widely owned by rural households in developing countries. Rural poultry production is not a primary agricultural activity per se, but rather serves to supplement other farming activities. Village chickens are the predominant poultry species in these areas, contributing significantly as a source of scarce animal protein and income. A range of challenges, which include diseases, parasites, mortality, predation amongst others, characterize village chicken farming, however. Of particular concern here is that a changing warming may compound or directly influence certain existing challenges to village chicken production. This study thus investigates the impact of climate change on village chicken production in Limpopo Province, South Africa. The particular focus is on four villages of Musina, namely: Madimbo, Malale, Domboni and Tshikudini. A baseline questionnaire was conducted across 106 households, and subsequently 30 households selected to participate in a monitoring study from February 2015 to February 2016. Further, trends were seasonal, annual and decadal scale ambient temperature and relative humidity trends for the period 1950-2016 were explored.

The study demonstrated that ambient temperatures have increased in Musina, indicating a general upward warming trend. Farmers also perceived various environmental changes, including ambient temperature increases. Despite most farmers reporting a reduction in productivity of village chickens over a period in which warming occurred, the general

perception was that rural poultry is hardy enough to cope with projected ambient temperature increases. Findings from this study revealed that village chickens may be negatively affected by heat stress, however. For instance, body mass gain had a negative correlation, albeit not significant, with increased environmental ambient temperatures. Further, observations of the behavioural thermoregulation (that is respiratory rates, wing orientation and shade-seeking behaviour) suggest that village chickens may be adversely impacted by climate-related heat stress, although with growers being more susceptible to the impacts than the hens and cocks.

The study concludes that climate warming is adversely impacting village chickens, likely causing heat stress. However, the extent to which the productivity of village chickens is compromised by heat stress may be less than that with commercial chickens, possibly due to better adaptation to local conditions. Future research should focus on establishing village chicken heat tolerance thresholds, as well as how farmers can strategically respond to a warming climate. Further, agricultural extension technical support is critical in helping farmers understand intricate climate change related challenges and opportunities for improving rural poultry farming.

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ACRONYMS

ANOVA	Analysis of Variance
AR	Assessment Report
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	The Department of Environmental Affairs
EC	Eastern Cape Province
FAO	The Food and Agriculture Organization of the United Nations
FREQ	Frequencies
GCI	Global Change Institute
HI	Heat Index
IPCC	Intergovernmental Panel on Climate Change
KZN	KwaZulu-Natal Province
Proc	Procedures
R^2	R-squared
SAS	Statistical Analysis Software
SAWS	South African Weather Services
SD	Standard Deviation
SDGs	Sustainable Development Goals
STL	Seasonal and Trend Decomposition by Loess

CHAPTER 1

1.0 Background

1.1. Introduction

This chapter highlights the key themes of the study. It contextualizes the research within what is currently known about climate change, small-holder farmers and village chickens. Further, it identifies key gaps in research and highlights the problem statement and justification, leading to the objective and specific aims. The final section of this chapter then outlines the structure of the thesis.

1.2. Food security challenges

Food security is related to all United Nations Sustainable Development Goals (SDGs), and exists when 'all people, at all times have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life' (Pérez-Escamilla, 2017, p 1). The worldwide agricultural sector faces an important challenge of increasing production to provide food security for a population projected to rise to 9 billion by 2050 (Rosenzweig et al., 2013). It is estimated that 800 million people are food insecure and that over two billion individuals experience key micronutrient deficiencies (FAO, 2015; Pérez-Escamilla, 2017). More than half of the population in low-income countries, such as those in sub-Saharan Africa, are food insecure (Ramakrishnan, 2002; Verpoorten et al., 2013).

Although, small-scale agriculture contributes about 60 – 66% of food consumed in Sub-Saharan Africa (Mapfumo et al., 2014), small-holder farmers are faced with numerous production challenges, including (but not limited to) pest and disease outbreaks and extreme

weather events, which can undermine their household food and income security (Hachigonta et al., 2013; Harvey et al., 2014). In fact, there is evidence that small-holder farmers represent about half of the hungry population worldwide, and probably three-quarters of the food insecure in Africa (Sanchez and Swaminathan, 2005; Pérez-Escamilla, 2017). Further, these farmers live in precarious conditions and are intrinsically vulnerable to shocks, such as climate change and variability, which affect their agricultural systems.

1.3. Climate change and subsistence farming

According to Solomon et al. (2007), Climate change refers to a change in the state of the climate, which can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Owing to substantial scientific evidence generated by scholars across the globe (IPCC, 2013), there is now a consensus that climate is changing (Tambo and Abdoulaye, 2013). Such changes in climate, which include flooding, droughts, erratic rainfalls and ambient temperature increases, are already affecting agricultural production systems. Small-holder and subsistence agriculture (that is, agriculture under small-based plots of land on which farmers grow subsistence crops and one or two cash crops relying almost exclusively on family labour) in developing countries is expected to suffer complex, localized impacts of climate change due to constrained adaptive capacity (Archer van Garderen, 2011; Shisanya and Mafongoya, 2016).

Although the livestock sector is an integral part of the rural agricultural economy, providing a safety net for poor households, it has generally received less attention, in terms of research, compared to crop production in the advent of climate change, especially in developing countries (DEA, 2013). Livestock production in rural communities may, however, be

seriously impacted by extreme ambient temperatures as a result of climate changes, particularly with the increase in number of hot days (Winsemius et al., 2014).

1.4. Village chickens and production challenges

Relative to other livestock types, poultry is widely owned by rural households in developing countries (Gondwe and Wollny, 2002; Mwale and Masika, 2009; Mtileni et al., 2012; Nyoni and Masika, 2012). Village chickens, also referred to as rural, backyard, indigenous, scavenging, traditional, local, native or family chickens, are the predominant poultry species in most rural communities of developing countries (Moreki, 2010). Village chickens play a very important role in the livelihoods of rural communities, supplementing household protein intake and contributing to household incomes, wealth, insurance against shocks, culture, religion, and tradition (Njenga, 2005; Sonaiya, 2007). These chickens are known to be hardy and thrive with limited inputs from rearers, making the best use of locally available resources in terms of feed and shelter (Ngeno et al., 2014). However, due to poor investments in this production system, productivity is usually very low compared to commercial production systems (Yusuf et al., 2014).

In general, feed quality and availability are important challenges in village chicken production (Acavomic et al., 2005). Although supplementary feed is sometimes provided, village chickens mainly depend on scavenging during daylight hours to meet their nutritional needs (Gondwe and Wollny, 2007). Supplementary feeding is usually irregular, non-selective and characterized by birds at different stages of growth, competing for the same feed (Muchadeyi et al., 2004).

In the evening, village chickens are housed in a range of ways, and, in some instances, chickens may roost in trees or in closed baskets hanging from trees (Mwalusanya et al., 2002; Acavomic et al., 2005). In general, poor housing in village chicken production contributes to high chicken mortality and morbidity (Mapiye and Sibanda, 2005). The problem of health in village chickens is further compounded by the interactions of different entities that are significant to disease epidemiology (Permin and Pedersen, 2002). At the village level, contacts between flocks of different households, the exchange of birds as gifts or entrusting sales and purchases, are the main sources of infection transmission. Further, it is likely that these birds are adversely affected (that is stressed) by extreme environmental conditions, due to their exposure to local prevailing weather conditions (Nyoni, 2011).

As mentioned earlier, ambient temperatures have increased during recent decades and are expected to continue increasing (Rosenzweig et al., 2008; Zhao et al., 2017). Ambient temperature directly impacts animals by causing them heat stress (Thornton et al., 2009). Heat stress, which includes a series of conditions where the body is under stress from overheating, is a major source of production loss in the poultry production industry, especially in hot regions (Lara and Rostagno, 2013; Bhadauria et al., 2014). A number of studies on heat stress and commercial poultry have been conducted globally (Bingsheng and Yijun, 2007; Soleimani and Zulkifli, 2010; Nääs et al., 2015), but there is still limited literature on the effects of heat stress on village chickens.

1.5. Problem statement and Justification

There is a paucity of information on the extent to which recent changes in climate have impacted on rural poultry production. Village chickens are constantly exposed to extremes of temperatures as they scavenge for feed, which may adversely affect productivity.

Productivity of village chickens is already compromised by several constraints and understanding the effect of climate change and variability will be important to accurately address each production challenge. It is thus essential to investigate recent changes in climate and the associated impacts on village chicken production. This information will create a platform for developing intervention strategies to improve and sustain rural poultry production. Further, increased subsistence production has the potential to reduce the vulnerability of rural food-insecure households, thereby improving livelihoods.

1.6. Aim and objectives

The aim of the study is to investigate the impact of climate warming on village chicken production in Musina, Limpopo Province, where baseline rural chicken production research has been initiated and some of the highest temperatures in South Africa are usually experienced.

Specifically, the following objectives are to be addressed:

1. To review literature on the importance of village chicken production and related constraints in the context of a warming climate. Focusing on:
   - *i. Highlighting the importance of and challenges facing rural poultry farming;*
   - *ii. Outlining climate warming trends in some areas where rural poultry production is an important enterprise;*
   - *iii. Reviewing literature on the impact of heat stress on livestock (in general) and poultry production (specifically); and,*
   - *iv. Outlining the possible impacts of climate warming on rural poultry farming.*
2. To understand recent variations in temperature and relative humidity trends. Focusing on:
   - *i. Analysing seasonal, annual and decadal temperature and relative humidity changes*

using daily weather data;

3. To establish rural farmers' perspectives on the likely impacts climate change may have on their village chicken production;
4. To determine seasonal variation in village chicken flock dynamics and management practices;
5. To examine the impact of heat stress on village chickens.

1.7. Null Hypotheses

1. Seasonal, annual and decadal temperature and relative humidity trends have not changed in Musina;
2. Rural farmers do not perceive climate change as a challenge in village chicken production;
3. There is no seasonal variation in village chicken flock dynamics and management practices;
4. Village chickens are not affected by heat stress.

1.8. Chapter outline

Chapter 1 has provided a background and introduction of this study, identified the research problem and defined the aim and objectives of the thesis.

Chapter 2 reviews the available literature on village chicken production, recent changes in climate and possible impacts of climate warming on village chickens in order to situate the study within the context of other related studies. The literature review addresses *Objective 1* of the study.

Chapter 3 analyses temperature and relative humidity trends in Musina. This chapter addresses *Objective 2.*

Chapter 4 establishes rural farmers' perspectives on the impacts that climate change may have on village chickens, and thus addresses *Objective 3.* Before adapting to climate change, farmers must first appreciate that changes are taking place, thus farmers' perceptions about climate change are very important.

Chapter 5 assesses seasonal flock dynamics and management practices in the villages of Musina Local Municipality, Limpopo Province, and therefore addresses *Objective 4.*

Chapter 6 investigates the impacts of climate warming on village chicken production in the villages of Musina. Behavioural thermoregulatory observations are made and deductions on the susceptibility of village chickens to heat stress are established. *Objective 5* is addressed in this chapter.

Finally, a general discussion is provided in ***Chapter 7***. Village chickens are susceptible to heat stress, especially during the hot season. However, heat tolerance levels of village chickens are probably higher than commercial chickens.

Chapters 2, 3, 4, 5 and 6 are presented as papers published/submitted for publication in peer reviewed scientific journals and are included in this thesis at various stages of publication.

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CHAPTER 2

2.0 Heat stress and chickens: climate risk effects on rural poultry farming in low-income countries

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(Published in Climate and Development)

2.1 Abstract

Compared to other types of livestock, poultry is widely owned by rural households in developing countries. Rural poultry production is not a primary agricultural activity per se, but rather serves to supplement other farming activities in resource-poor rural communities, and thus contributes significantly as a source of scarce animal protein and income. Rural poultry farming is, however, faced with several challenges, including inherent slow growth rates, high rearing mortalities and susceptibility to diseases, poor nutrition and housing, and insufficient health care, which may impede production. An added concern is that unprecedented climate warming may compound some of these challenges. This paper reviews the potential impact of such climate warming on rural poultry farming, which may then provide knowledge to help inform intervention strategies to assist sustainable production. Particular focus is on how climate-warming trends have impacted on heat stress experienced by livestock, the importance of rural poultry, and challenges faced in rural poultry production in developing countries. Although these birds are generally known to be hardy, it appears that some losses experienced in rural poultry farming may be a direct or indirect consequence of climate-related stresses. There is a clear need for urgent research attention in this domain, so as to improve appropriate management strategies and responses to rising ambient temperatures.

Key words: climate change, heat stress, poultry, subsistence

2.2 Introduction

The Intergovernmental Panel on Climate Change Fifth Assessment Report (5th AR, IPCC 2013) made three fundamental deductions that form the basis of this review. Firstly, the assessment emphasised that warming of the climatic system is unequivocal, and that anthropogenic warming will continue for centuries to come due to timescales associated with climate processes and feedbacks. Secondly, surface air temperature warming is projected to increase by between 1.5 and 3.5°C for low scenarios and between 3.0 and >6.0°C for high scenarios during the 21st century. The report further stressed that more frequent warm spells and heat waves are to be expected.

While stresses caused by climate change are likely to negatively impact the agricultural sector and escalate existing small-scale farming challenges, agricultural productivity has to improve to meet the needs of an ever-increasing population (Zamykal and Everingham, 2009; DEA, 2013). In most developing countries, such as South Africa, the livestock sector is critical to the agricultural economy, yet, in the context of climate change, it has typically received less attention than the crop-farming sector. In fact, according to the 5th Assessment Report (IPCC, 2013), research focusing on the impacts that climate warming has on livestock is relatively limited, especially in developing countries.

Relative to other types of livestock, poultry is widely owned by rural households in developing countries (Gondwe and Wollny, 2002; Nyoni and Masika, 2012). Poultry plays a significant role in the livelihoods of rural communities, supplementing household protein intake and as a source of additional income. Although rural poultry production is not an occupation per se, it often supplements household income, primarily for poor families.

Several authors (for example Swatson et al., 2002; Sharma, 2007; Ndegwa et al., 2015) have argued that strengthening rural poultry production may help overcome poverty and malnutrition in impoverished communities. However, poultry production in many developing communities is frequently characterized by management challenges and low productivity and is faced with several other constraints. Of growing concern is that climate change may be impacting on chicken growth and production, and ultimately overall poultry production.

Of all bioclimatic parameters, ambient temperature is considered the most important factor affecting livestock, as it has a direct impact on animals, often causing heat stress (Thornton et al., 2009). Heat stress causes production losses in the intensive poultry production industry, particularly in hot, resource limited regions of Africa and Asia (DAFF, 2013; Bhadauria et al., 2014). Several reviews have explored possible impacts of a hot climate on poultry production systems – focusing on the physiology and detrimental effects of heat stress (Tankson et al., 2001; Lara and Rostagno, 2013; Bhadauria et al., 2014; Winsemius et al., 2014). From such studies, it is evident that high ambient temperatures impose adverse consequences on performance and productivity of commercial poultry. However, a notable remaining research gap has been on how heat stress is impacting rural poultry production in particular, especially given the importance of such birds to improve food security in poor households.

In commercial production systems where, environmental microclimates are well controlled, local climate (or climate change) may not be of significant concern. However, in rural areas of developing countries, it is likely that rural poultry is adversely affected (that is stressed) by extreme environmental conditions, as birds continue to interact with the local environment during scavenging, and farmers have less capacity to control their living environments. Such

concerns are echoed by Winsemius et al. (2014), who caution that subsistence farming in developing countries is vulnerable to extreme weather conditions, and that livestock in rural settings may be seriously impacted during exceptionally hot days, consequently impeding productivity.

The current paper investigates the challenges of rural poultry production in the context of climate warming in developing countries. The key objectives of the study are to: i) briefly highlight the importance of, and the challenges facing, rural poultry farming; ii) review available literature on the impact of heat stress on livestock (in general) and poultry (in particular); and iii) outline the possible impact of climate warming on rural poultry farming.

2.3 Importance of rural poultry

Poultry production broadly refers to the rearing of birds such as chickens, ducks, geese and turkeys. Chicken production is a predominant global farming subsector and has been an important food source for humans for over 8000 years (Muchadeyi et al., 2004). The highest chicken densities (that is greater than 10,000 birds per km^2) are found in certain parts of western Europe, eastern USA, central Brazil, and eastern and southern Asia (see Fig. 2.1) (Robinson et al., 2014). High chicken densities seem to be correlated with intensive commercial production systems (Bingsheng and Yijun, 2007; Nääs et al., 2015). However, chicken production in Indonesia, particularly on the Island of Java, seems to be an outlier with high chicken densities per km^2 produced extensively in backyard operations (Daghir, 2008).

Africa has fairly low chicken densities, with wide distributions in West Africa and some pockets of high density in South Africa and around the shores of Algeria and Egypt. The

apparent low chicken densities in Africa are likely due to poor statistical information from most African countries (Daghir, 2008). Available chicken density maps (for example Fig. 2.1) indicate higher numbers in major urban centres such as Johannesburg/Pretoria (South Africa), Algiers (Algeria) and Cairo (Egypt), from which statistical information has been forthcoming. However, the relatively high urban poultry densities are likely associated with both commercial (broilers and layers) production and some backyard chickens being accounted for.

South Africa has an average of ~11 households per km2 (Stats SA, 2012), and given that most households rear ~22 chickens in Limpopo Province (Malatji et al., 2016), chicken density in this region should approximate at least 220 birds per km2 (Fig. 2). Similarly, in KwaZulu-Natal (KZN) and the Eastern Cape (EC) provinces, birds number ~28 and 30 per household respectively (Malatji et al., 2016; Yusuf et al., 2014), and hence estimated densities of 310 and 330 birds per km2 respectively. Hence, globally recognized world chicken density maps such as that by Robinson et al. (2014) (Figure 1) are likely grossly under-estimating chicken densities across large parts of Africa.

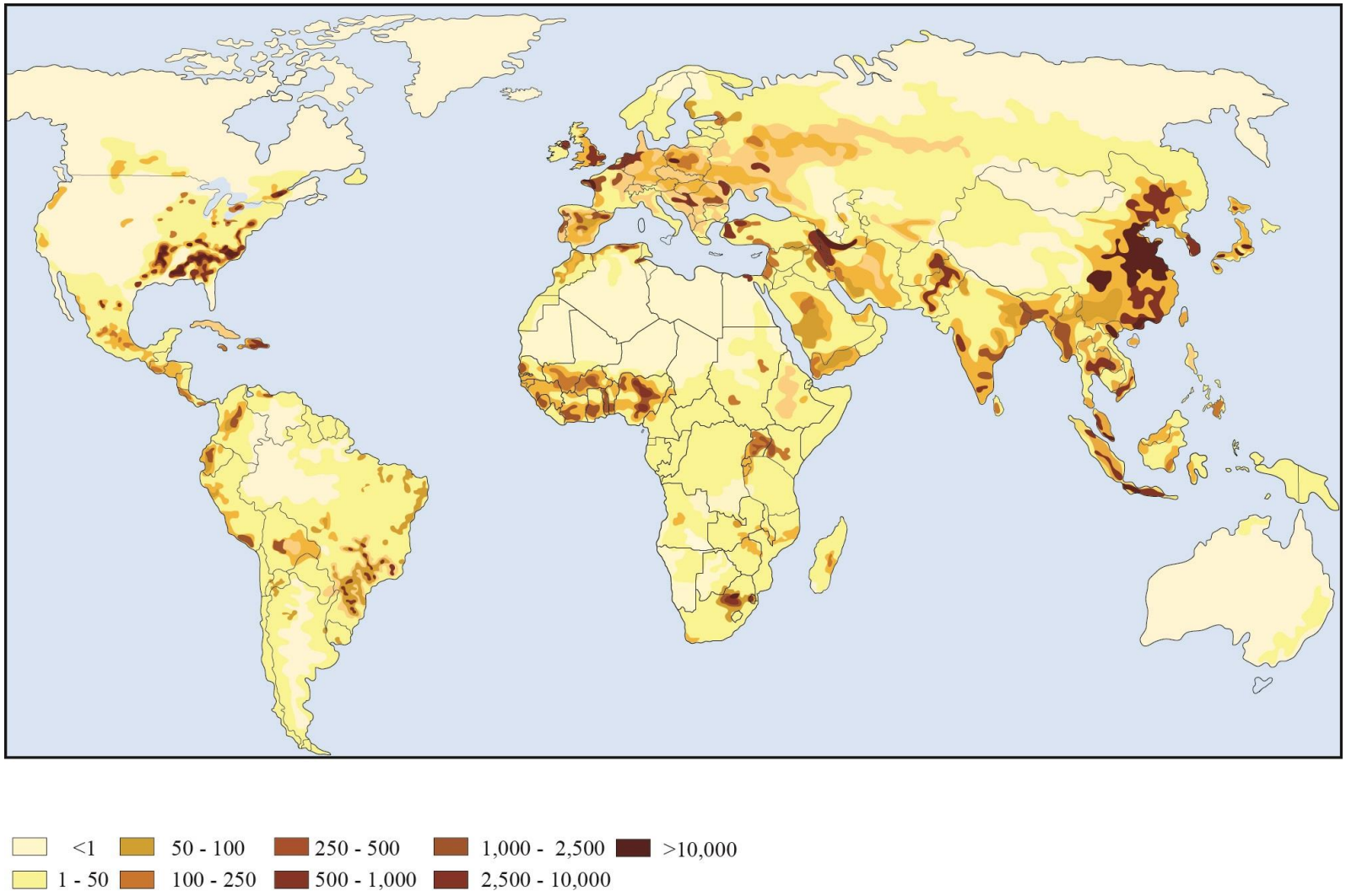


Figure 2.1: Global distribution of chickens (birds/km^2) (Source: Robinson et al., 2014)

A number of studies undertaken in many resource-limited communities (for example Awan et al., 1994; Alders et al., 2007; Sekeroglu and Aksimsek, 2009; Nyoni and Masika, 2012; Mwacharo et al., 2013; Bhadauria et al., 2014) have found that poultry production is common in rural areas and mainly constitutes nondescript village chicken breeds. These chickens are also commonly referred to as 'rural', 'backyard', 'indigenous', 'scavenging', 'traditional', 'local', 'native' or 'family' chickens, depending on local terminology (Moreki et al., 2010). Village chickens play an important role in the livelihoods of rural communities, supplying quality food in the form of meat and eggs, as well as secondary income (Reta, 2009; Nyoni and Masika, 2012; Nebiyu et al., 2013). In Ethiopia, village chicken production is perceived to alleviate poverty by providing income generating opportunities (Nebiyu et al., 2013). According to Reta (2009), chickens are also considered as the last resource for poor farmers, indicating that these are often the last capital items that households have left when transitioning into a state of poverty. Poultry further has socio-cultural functions in everyday village life (Zaman et al., 2004), such as providing chickens as gifts or as tokens of appreciation for services rendered (Muchadeyi et al., 2004). Reports from Mozambique (Alders et al., 2007), Botswana (Moreki et al., 2010) and Kenya (Kingori et al., 2010) have observed that poultry in rural areas contributes towards the mitigation of HIV/AIDS through improved food security and income generation. In addition, because these birds are hardy (van Marle-Köster et al., 2009), farmers recognize considerable production benefits with minimum input in terms of time commitment, feed, housing and general health management aspects.

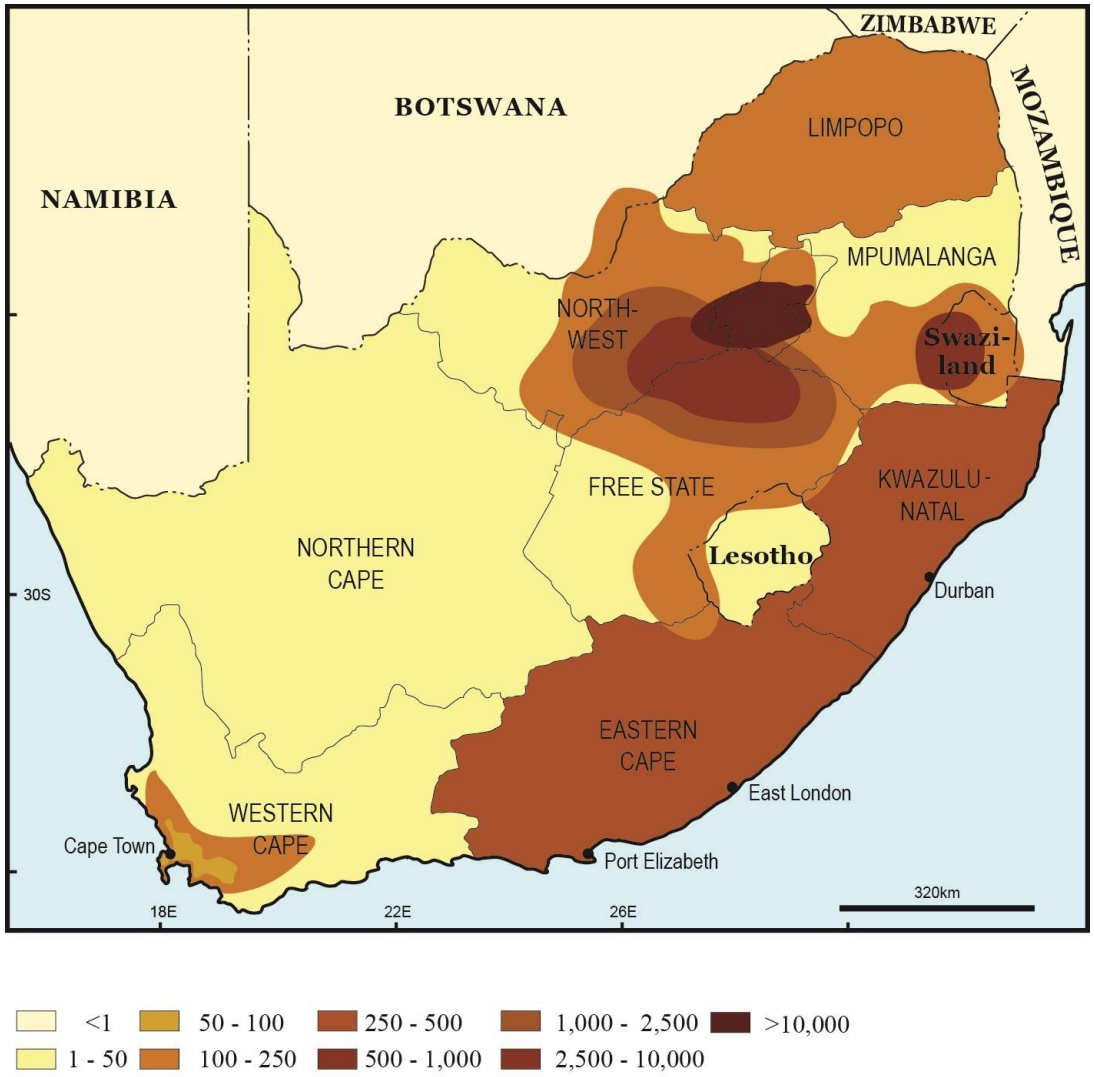


Figure 2.2: South African map showing chicken density in 3 provinces – Limpopo, KwaZulu-Natal and Eastern Cape

2.4 Challenges facing rural poultry production

Notwithstanding the aforementioned potential roles poultry can play, rural poultry production nonetheless faces a variety of challenges, including amongst others: inherent slow growth rates, poor egg production, poor nutrition, lack of adequate housing and health care, predation and high mortalities (Swatson et al., 2002; Kingori et al., 2010). Such challenges pose a significant threat to the sustainability of rural poultry production in developing regions.

Some reports (for example Mapiye et al., 2008; Nebiyu et al., 2013) have argued that rural poultry productivity with respect to the number of eggs laid per clutch, chicks hatched per clutch, and chick survival to maturity is very low in comparison to layers in intensive systems. For example, in the commercial sector, chickens lay one egg every 23–26 hours and rest as little as 24 hours between periods of laying (that is clutches). In contrast, village chickens may lay an egg after 2–3 days for about 4 weeks, but rest for several months between clutches (Nebiyu et al., 2013).

Although supplementary feed is sometimes provided, rural poultry mainly depends on scavenging for nutritional needs (Gondwe and Wollny, 2007). Supplementary feeding is usually irregular, non-selective and characterized by birds at different stages of growth competing for the same feed (Muchadeyi et al., 2004). This results in weaker groups, such as chicks, receiving inadequate nutrition (Tadelle and Ogle, 2001). In addition to this rural poultry production system affecting nutrition, it may further expose birds to parasitism and predation during scavenging (Nyoni and Masika, 2012). Simultaneously, climate change (warming) is becoming increasingly evident across most regions globally and may have adverse effects on the welfare of poultry. In fact, observed increases in ambient temperatures are likely to cause heat stress on poultry (DEA, 2013), especially in rural settings where there

is limited understanding on how environmental conditions impact poultry, and consequently on the associated best management practices. It is thus important to begin assessing the dynamics of rural poultry production in a warming climate.

2.5 Climate warming and livestock production

Global temperatures have substantially increased over recent years, such that between 1980 and 2016, increases of over 1°C have been recorded over vast terrestrial regions (Fig. 2.2). Such increases, even at the lower end of the range, are expected to have far-reaching impacts on food production and food security (Archer et al., 2008; Thornton et al., 2014). Small-scale and subsistence farming in developing countries (especially in Africa) is expected to suffer complex and localized consequences due to climate change and constrained adaptive capacity (Archer van Garderen 2011; Shisanya and Mafongoya, 2016). The situation is likely to be compounded in regions such as southern Africa where mean temperatures have increased by up to 1.5 times more than that of the observed global average between 1960 and 2010 (DEA, 2013; Kruger and Sekele, 2013).

Several biotic factors such as a species' genetic potential, life stage and nutritional status, may determine the level of vulnerability to heat stress (Thornton et al., 2009). According to Huey et al. (2012), species with high physiological capacities to buffer environmental variations and high potential for rapid evolution are better equipped to survive rapid warming. The level of tolerance to high environmental temperatures is also determined by the species' place of origin. Animals that have not been exposed to high ambient temperatures are generally more vulnerable to heat stress than those that have adapted (acclimatized) over time (Sirohi and Michaelowa, 2007). For instance, Nguni cattle, which are indigenous to South Africa, are well adapted to hot environmental conditions compared to imported breeds

such as Hereford, Aberdeen Angus and Simmental from the cold regions (Ndlovu et al., 2009).

2.6 Heat stress and poultry production

Heat stress is one of the most important environmental challenges adversely affecting poultry production worldwide (Kadim et al., 2008). Understanding and buffering environmental conditions is thus imperative to successful poultry production. As with other livestock, birds maintain a relatively constant internal body temperature through physiological and behavioural thermoregulation (Mustaf et al., 2009). Physiological thermoregulation entails changes in the upper critical ambient temperature where birds would have to initiate evaporate cooling to prevent body temperature from increasing (Graux et al., 2011; Chand et al., 2014). In contrast, behavioural thermoregulation involves changes in posture, orientation and/or microclimate selection in order to reduce heat loads. Ambient temperatures above 30°C generally impact negatively on chickens and cause a reduction in feed intake and body mass, and on occasion, high mortality of broilers (Yahav et al., 1995; Tankson et al., 2001; DAFF, 2013). In addition, major attributes of poultry meat quality (that is appearance, texture, juiciness, flavour, and functionality) are significantly decreased in heat-stressed broilers (Feng et al., 2008).

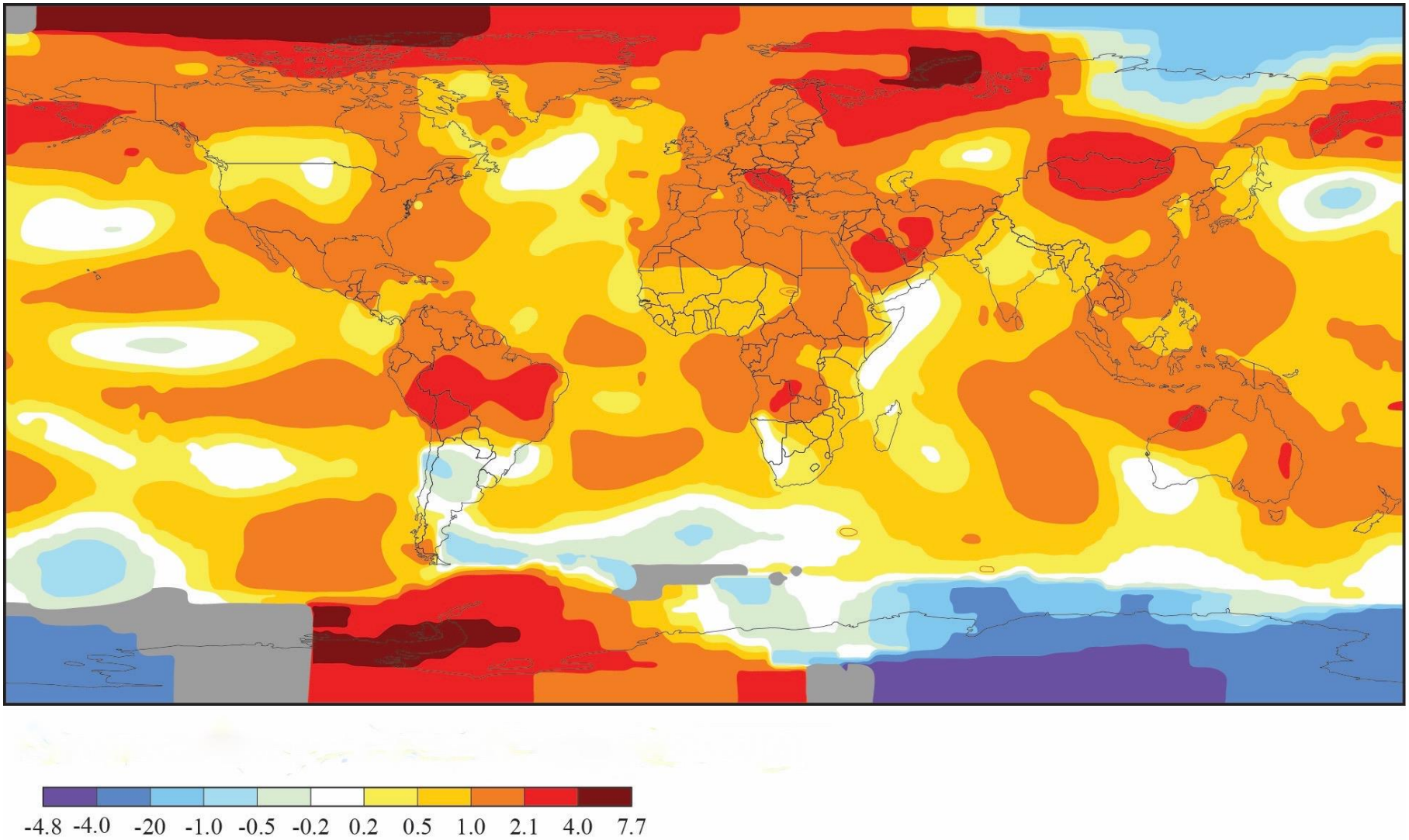


Figure 2.3: Global temperature (°C) trends (1980 - 2016) (Sources: GISTEMP Team, 2016; Hansen et al., 2010)

Since the 1980s, there has been considerable interest in the relationship between commercial poultry production and heat stress, from establishing the impacts of heat stress to intervention strategies. Some earlier studies have associated selection for rapid growth with increased susceptibility of poultry (particularly broilers) to heat stress, given that with rapid growth rates, the basal metabolic rate of broilers is increased (for example Cahaner et al., 1995; Berong and Washburn, 1998; Nienaber and Hahn, 2007). In turn, this generates more heat, which may eventually cause bird mortality if the birds are not able to dissipate heat. Since rural poultry is characterized by slow growth rates, it is possible that they are less susceptible to the impact of heat stress due to prior exposure. However, as mentioned earlier, studies focusing on the impacts of rising ambient temperatures on rural poultry production remain largely absent.

Recent research suggests that all birds generally react in a similar manner to heat stress but may express individual variation of intensity and duration of responses (Lara and Rostagno, 2013). This report concurs with earlier studies (for example Hemsworth, 2003; Boissy et al., 2007) arguing that variations might occur when other stressors such as limited housing space and insufficient ventilation accompany heat stress. Findings from Malaysia similarly concluded that the susceptibility of birds to heat stress is not determined by genetic differences in body size and age, but rather by domestication and selective breeding (Soleimani et al., 2011). In addition, Soleimani and Zulkifli (2010) explain how selection for fast growth correlates with vulnerability to heat stress. Other studies (for example Felver-Gant et al., 2012; Mack et al., 2013), however, have suggested that much variation is genetically based, and that genetic selection could be a useful strategy for reducing the impact of stress on birds. Such divergent views on the significance of genetics necessitate further investigations, especially in rural poultry production where research is limited.

Stressful heat conditions not only reduce feed intake and body mass, but also affect reproductive performance of laying hens by interrupting egg production (Mashaly et al., 2004; Abidin and Khatoon, 2013). Earlier studies ascertained that heat stress disrupts hormones responsible for ovulation and decreases responsiveness of granulosa cells to luteinizing hormone in hens (Donoghue et al., 1989; Novero et al., 1991). As a result of the change in hormones, egg production, egg weight, shell weight and shell thickness are considerably compromised resulting in poor egg quality (Renaudeau et al., 2012). Given standard room temperatures of between 20 and 24°C, normal respiratory rates of adult birds will range between 20 to 59 breaths per minute (Swick, 1998; Marchini et al., 2007). However, as ambient temperature increases, birds tend to increase their respiratory rate to as much as 151 breaths per minute for heat stressed broilers (Nascimento et al., 2012). Although panting helps birds lose excess body heat to the environment (Fedde, 1998; Lara and Rostagno, 2013), studies on breeders and layers demonstrated that increased panting ultimately reduces blood bicarbonate availability for eggshell mineralization, consequently impacting negatively on egg production (Marder and Arad, 1989; Mashaly et al., 2004; Renaudeau et al., 2012)

2.7 Possible impacts of climate warming on rural poultry farming

Although rural poultry is generally perceived to be hardy and well adapted to harsh, stressful environments, scientific information that backs these claims is limited. Since rural poultry is usually exposed to prolonged high ambient temperatures (in hot regions) during scavenging, it is likely that they have genetically adapted to a warming climate. However, both the impact of increased frequencies of heat waves and critical heat stress threshold levels on rural poultry have not been scientifically established.

One behavioural strategy for coping with stressful heat conditions could be seeking shade. Such behaviour has been observed and reported for other livestock such as cattle, sheep and goats, where animals seek shade, drink water and/or change posture to maintain core body temperature under hot environmental conditions (Renaudeau et al., 2012; Vizzotto et al., 2015; Kerr, 2015). Although this significantly reduces radiant heat load, actively seeking shade during the day may result in inadequate feed intake, especially for livestock such as rural poultry which depend heavily on scavenging around homesteads during the day for their nutritional needs.

It is likely that as rural poultry dissipate excess heat, they may pant excessively, especially during summer when high ambient temperatures are experienced. Under this premise, it is possible that the observed low poultry output (in terms of eggs produced and number of birds consumed and/or sold) (Aboe et al., 2006) in some small-scale rural poultry farming regions may, in part, be a function of heat stress. It is also possible, however, that as in the case of Nguni cattle, which have a more efficient thermoregulation system compared to imported breeds (Ndlovu et al., 2009), rural poultry has a relatively higher level of heat tolerance than breeds in commercial settings. However, the extent and variation of ambient temperature tolerance thresholds in rural poultry remains unknown and is thus a knowledge gap that requires urgent attention.

2.8 Conclusion

Although rural poultry contributes significantly to the livelihoods of households in many developing regions worldwide, the sector is constrained by multiple challenges such as climate change. Of particular concern is that a changing climate may compound or directly

influence some of the already existing challenges in rural poultry production, such as slow growth rates and poor egg production. At the same time, based on genetics and adaptation, it is likely that local breeds may do better than commercial breeds under projected climate warming. However, this subject is still poorly understood and thus constitutes an important future research strand in poultry science.

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CHAPTER 3

3.0 Temperature and relative humidity trends in Musina, South Africa: 1950–2016

(Submitted for publication in the South African Journal of Science)

3.1 Abstract

Musina is located in one of the warmest regions of South Africa, and the agricultural sector here is thus prone to heat stress. The aim of this study is to explore air temperature and relative humidity trends for the region, which have implications for agricultural adaptation and management. In particular, the study investigates seasonal, annual and decadal scale temperature and relative humidity changes for the period 1950-2016. Positive temperature trends were recorded for this period, averaging +0.02°C year^{-1}, with the strongest changes in mean maximum summer temperatures (+0.03°C year^{-1}). Inter-annual temperature variability has also increased over time, especially for the period 2010-2016, which presented probability densities of <5% for minimum temperatures. Positive trends (+0.06% year^{-1}) in mean relative humidity are also recorded for the period 1980-2016. Relative humidity was, however, the least predictable weather parameter, with probability densities of <0.5% across seasons for the study period. Considering the substantial inter-annual variability in temperature and relative humidity, there is increased risk for the agricultural sector, particularly for small-scale farmers who have limited capacity to adapt. Climate science in the southern African region should continue to establish the impact of climate changes and variability on specific small-scale farming systems and enterprises, and consider relevant downscaled adaptation options.

Key words: agriculture; climate change; heat index; heat wave; northern South Africa

3.2 Introduction

Globally, mean temperatures have increased on average by 0.6°C over the past century, while extreme rainfall events have also increased in frequency (IPCC, 2013; Ziervogel et al., 2014). It is widely projected that as the earth becomes warmer, climate and weather variability will increase (Department of Environmental Affairs, 2013; Thornton et al., 2014; Diallo et al., 2015; Engelbrecht et al., 2015). Such changes in climate present a significant threat to food security, water resources, health and infrastructure (Ziervogel et al., 2014).

Given their poor adaptive capacity in terms of finances, resources, infrastructure and expertise, low-income regions are thought to be the most vulnerable to extreme climatic events (Keggenhoff et al., 2015). In particular, the small-scale farming sector, which contributes significantly to national food security in developing countries, is an exposed and vulnerable production system (Hachigonta et al., 2013). The situation is compounded in cases where there are limited reliable historical climate data available to establish climatic trends; a concern that holds true for most African countries.

In order to develop a sustainable adaptive capacity for target regions and address current and future challenges presented by climate variability and/or change, it is valuable to evaluate historical trends (Jury, 2013). Process-based regional and global climate models generally have the ability to replicate large-scale climate features; however, their coarseness in spatial resolution often fails to provide adequate information at local scales (Tadross et al., 2005; MacKellar et al., 2014). The use of region-specific past-observed climatic records, where possible, has the potential to assist on-going climate modelling and projections to establish the likely impact of changes in the climatic system on agricultural productivity, and ultimately food security.

Several studies on historical weather and climatic changes have focused at the country level in South Africa (for example Kruger and Shongwe, 2004; Jury, 2013; Kruger and Sekele, 2013; MacKellar et al., 2014), while others are more region specific with finer spatial detail (for example Gbetibouo, 2009; Tshiala et al., 2011; Kalumba et al., 2013; Lakhraj-Govender et al., 2017). The study by Gbetibouo (2009) for the Limpopo Basin area in northernmost South Africa provides some information on climatic trends for the region. The study mainly focused on farmers' perceptions and adaptation to climate change and variability, rather than a detailed analysis on climatic trends. A further study on Limpopo Province focused on 30 catchments, analysing annual and seasonal minimum and maximum temperatures for the period 1950-1999 (Tshiala et al., 2011), but did not include relative humidity. However, in the context of agricultural and human/animal comfort sectors, a combination of these two weather parameters (that is temperature and relative humidity) is important for establishing heat indices - a measure of how hot it feels. Our study thus aims to provide a better understanding of recent temperature and relative humidity trends in the Musina region of northern South Africa, which has implications for determining heat stress. Particular focus is on analysing seasonal and annual temperature and relative humidity trends for the period 1950-2016.

3.3 Materials and methods

3.3.1. Description of study site

This study was undertaken in the rural areas of Musina Local Municipality in Limpopo (see Fig. 3.1), where many households rear poultry for subsistence purposes. This province is regarded one of the poorest in South Africa, with several pockets of extreme poverty, and inequality patterns that significantly impact semi-skilled and unskilled workers (Lehohla, 2012). Musina Local Municipality has four villages located within 25km of each other, which include: Madimbo, Malale, Domboni, and Tshikhudini. Annual mean minimum and maximum temperatures are ~16°C and ~30°C, respectively. Notably, the highest annual maximum temperature in summer may reach ~45°C (Makhado et al., 2016), making this site ideal for my research on the impact of climate warming on rural poultry.

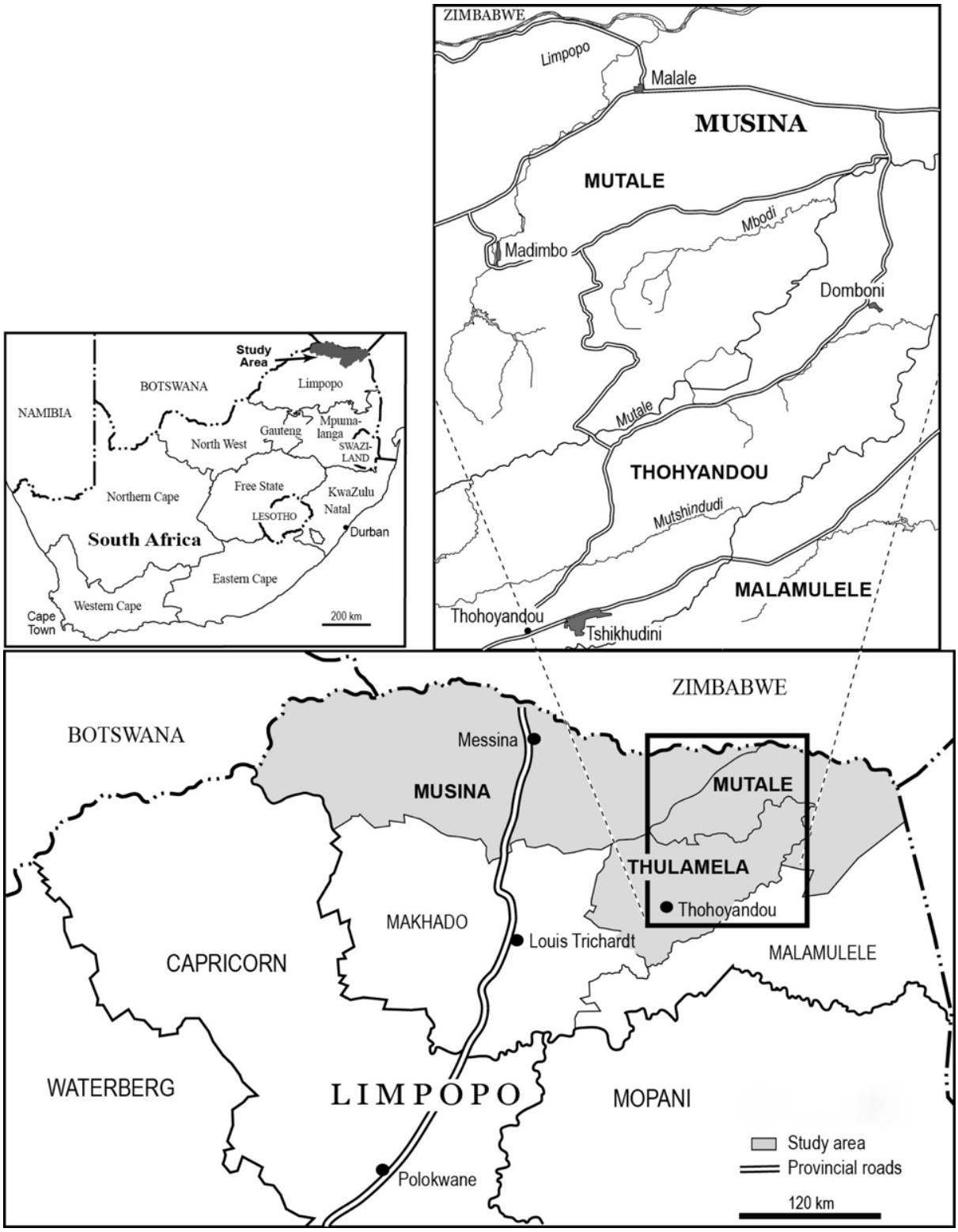


Figure 3.1: The location of four villages that participated in the study within Musina Local Municipality, Limpopo Province, South Africa

3.3.2. Data collection

Daily temperature (1950-2016) and relative humidity (RH) (1980-2016) data for Musina were provided by the South African Weather Service (SAWS). Data were scrutinized to identify missing and incorrectly reported or recorded values. Missing and/or incorrect values were then replaced using temporal interpolation techniques (hierarchical polynomial regression techniques, in particular) as described by Boissonnade et al. (2002). In addition, change points were identified (Vincent et al., 2012) and homogenized using the quantile-matching (QM) adjustment method (Wang et al., 2014). Using the QM method, up to 10 years of data (where possible), before or after a change point, were used to produce reliable adjustments (Wang et al., 2014; Vincent et al., 2012).

3.3.3. Data analyses

Temperature and relative humidity trends were determined using R software packages lubridate and forecast, and assisted by the Seasonal and Trend Decomposition by Loess (STL) function. Loess (locally weighted smoothing) is used in regression analysis for creating a smooth line through a timeplot, thus demonstrating the relationship between variables and forecast trends. Graphs plotted from STL have four components, including 1) the original data (that is a set of actual values), 2) a seasonal component calculated using loess smoothing, 3) the trend (that is increasing or decreasing direction in the data), and 4) the remainder representing the residual.

The total number of heat-wave days was calculated for each year. Threshold values for a heat wave are based on the average maximum temperature of the hottest month of a given year plus 5°C, as prescribed by the SAWS. The totals per year were only for heat-wave days that

formed part of actual heat waves (that is where the maximum temperatures exceeded the threshold for three or more successive days).

Probability density plots, calculated using R software package ggplot2 and tested for significance at the 95% confidence level, were used to establish variability of temperature and relative humidity across seasons and decades. Density plots provide a relative likelihood of these random variables falling within a particular range of values. The heat index (ºC) was calculated using weathermetrics (Anderson and Peng, 2012). Maximum ambient temperatures and relative humidity were used to determine the heat index.

3.4 Results

3.4.1. Temperature trends

Time series graphs show positive trends in temperature, with averages marked for each month over the 1950- 2016 period (see Figures 3.2, 3.3 & 3.4). Summer maximum temperatures recorded the fastest rate of increase (+0.03°C year^{-1}) compared to other seasons and other temperature parameters (that is average and minimum). Seasonal and trend decomposition of temperatures show that mean maximum temperatures ranged between 28 and 33°C (see Fig. 3.5), while average temperatures ranged from 21 to 25°C (see Fig. 3.6), and mean minimum temperature ranged from 14 to 18°C (see Fig. 3.7). The absolute highest and lowest recorded temperatures were during the summer of 2007 (45.1°C) and winter of 1972 (-3.8°C), respectively.

The strongest positive warming trends are noted for the past three and a half decades (that is from 1980-2016). For instance, mean annual maximum temperatures increased at a rate of +0.019°C year^{-1} between 1950 and 1986, but substantially increased to +0.031°C year^{-1} for

the period 1980-2016. However, mean annual temperatures have only increased marginally more (0.022°C year^{-1}) over the 1980-2016 period, compared to the period 1950-1986 (0.021°C year^{-1}). However, none of the warming trends (that is for the periods, 1950-2016, 1950-1986 or 1980-2016) is statistically significant at the 95% confidence level.

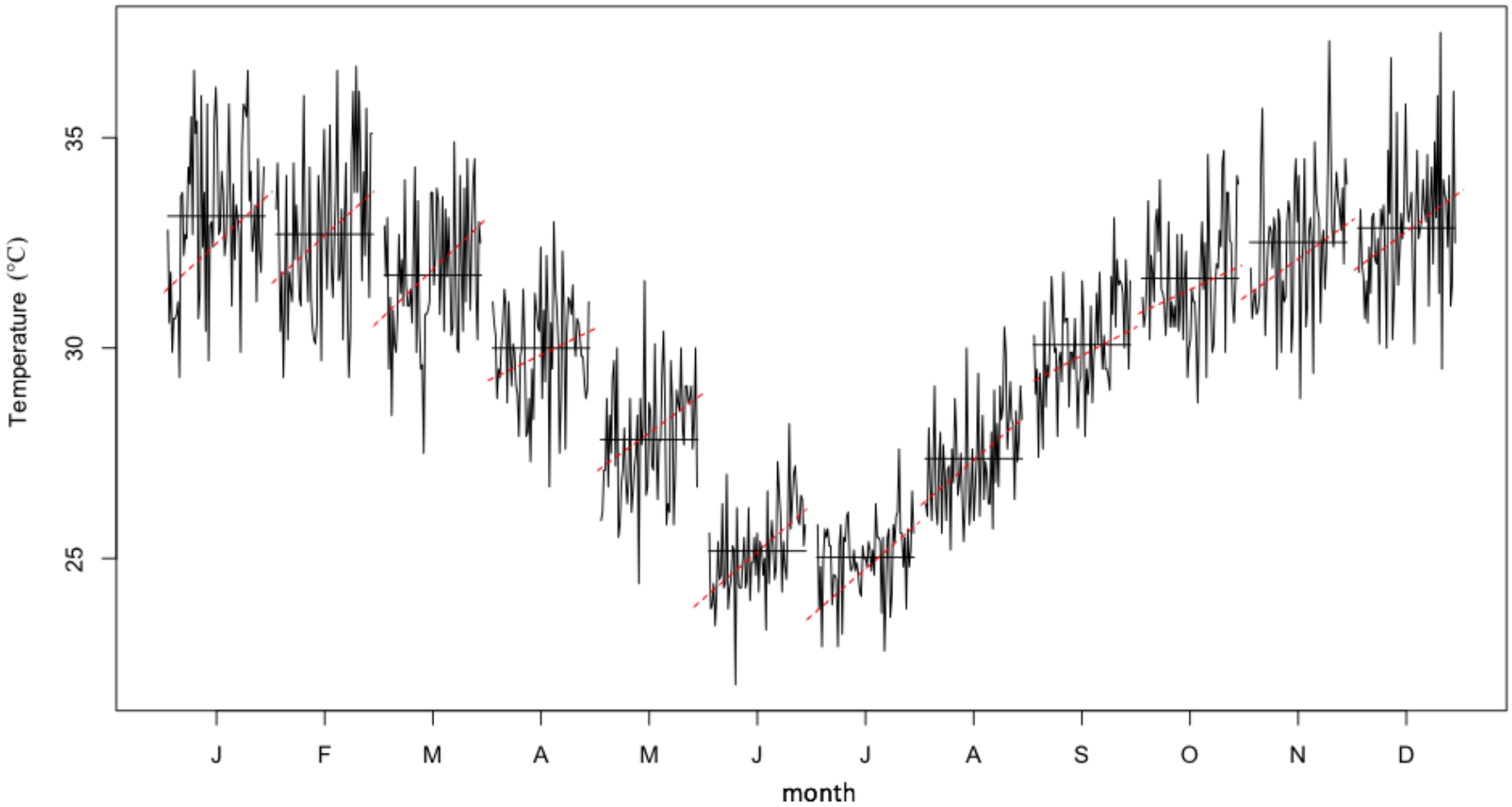


Figure 3.2: Mean monthly maximum temperature per year (1950-2016) for Musina. Horizontal lines = monthly mean values / red dotted lines = trend lines. Data were provided by the South African Weather Service (SAWS).

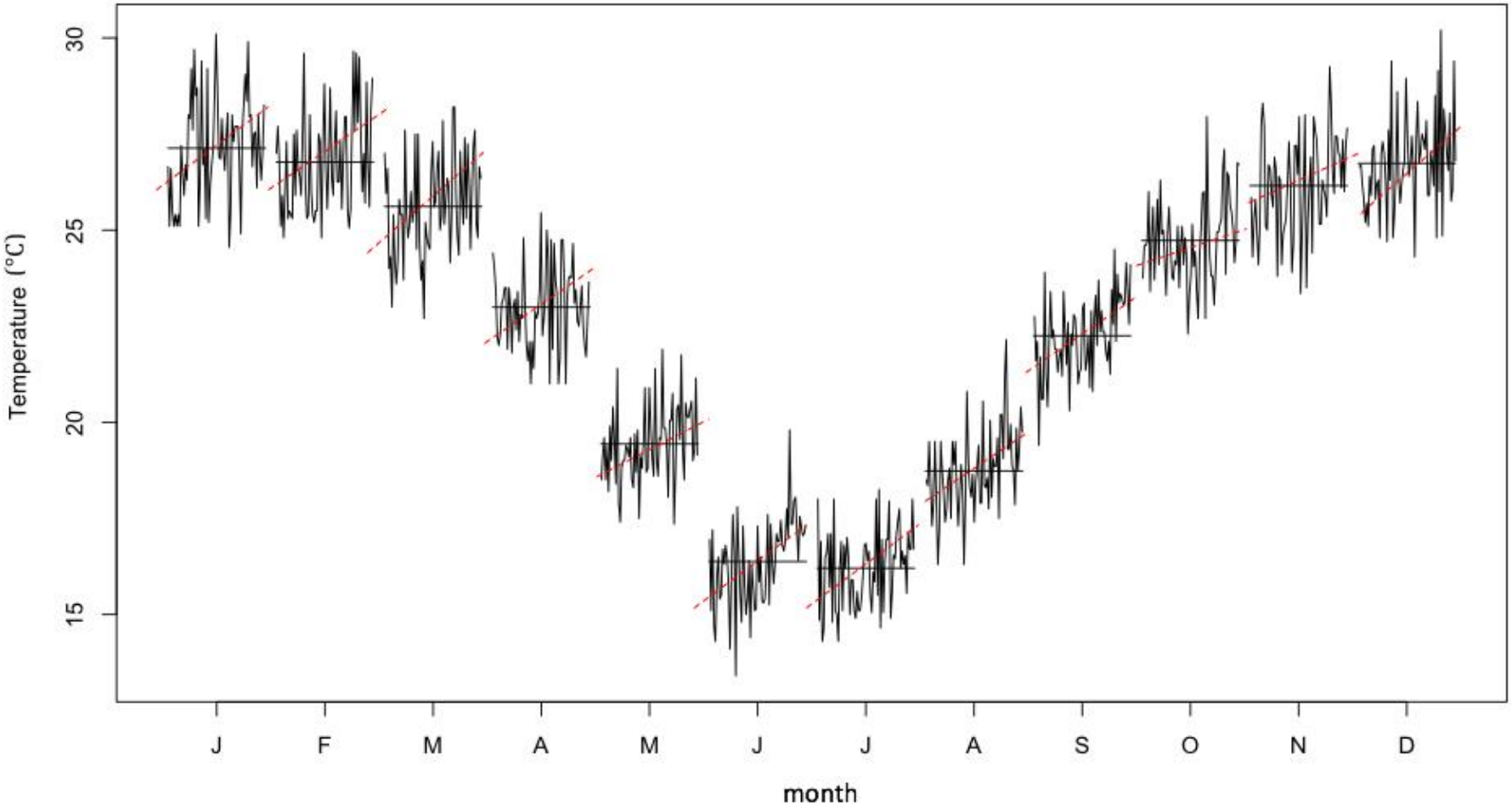


Figure 3.3: Mean monthly average temperatures per year (1950-2016) for Musina. Horizontal lines = monthly mean values / red dotted lines = trend lines. Data were provided by the South African Weather Service (SAWS).

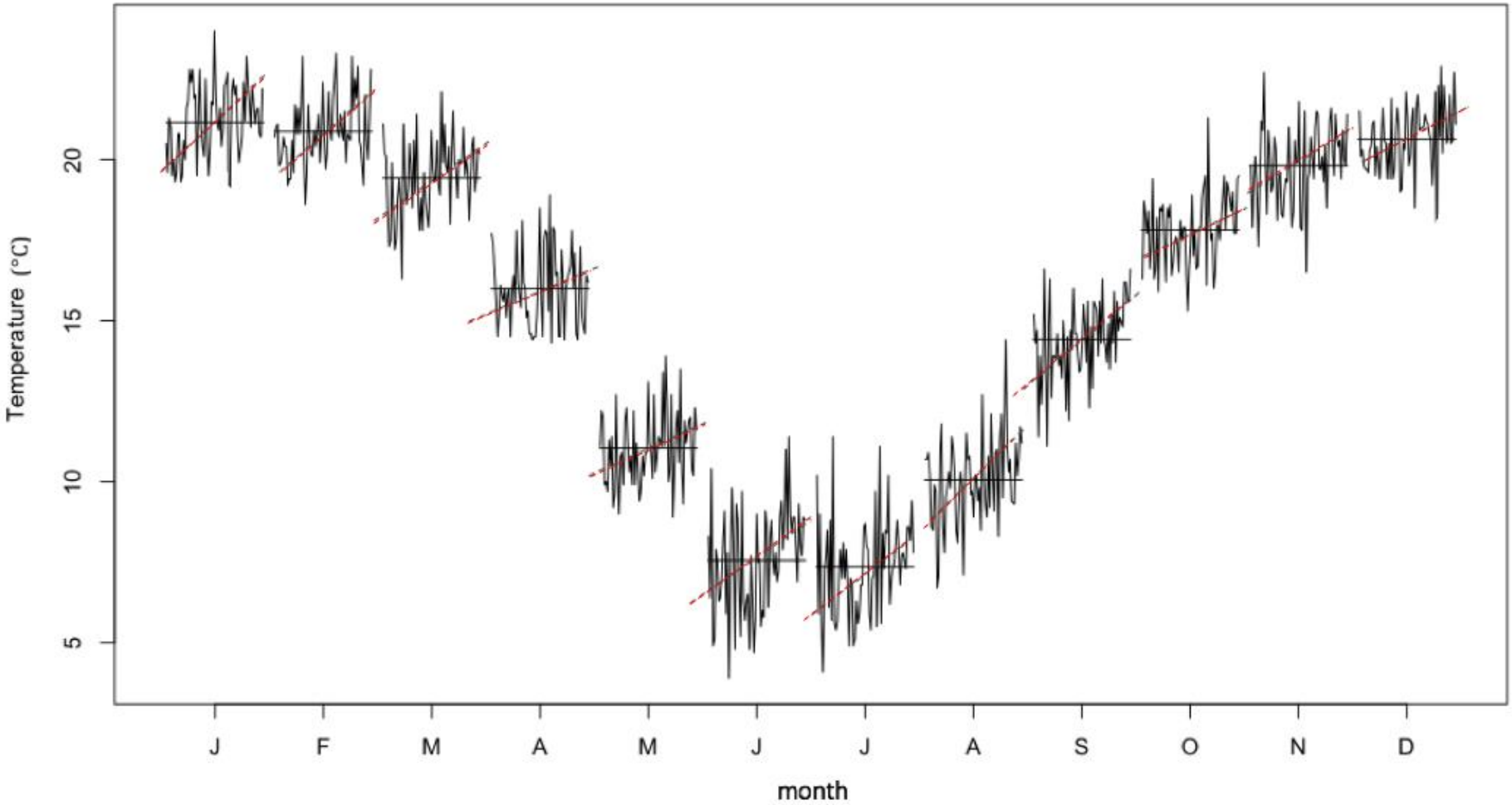


Figure 3.4: Mean monthly minimum temperatures per year (1950-2016) for Musina. Horizontal lines = monthly mean values / red dotted lines = trend lines. Data were provided by the South African Weather Service (SAWS).

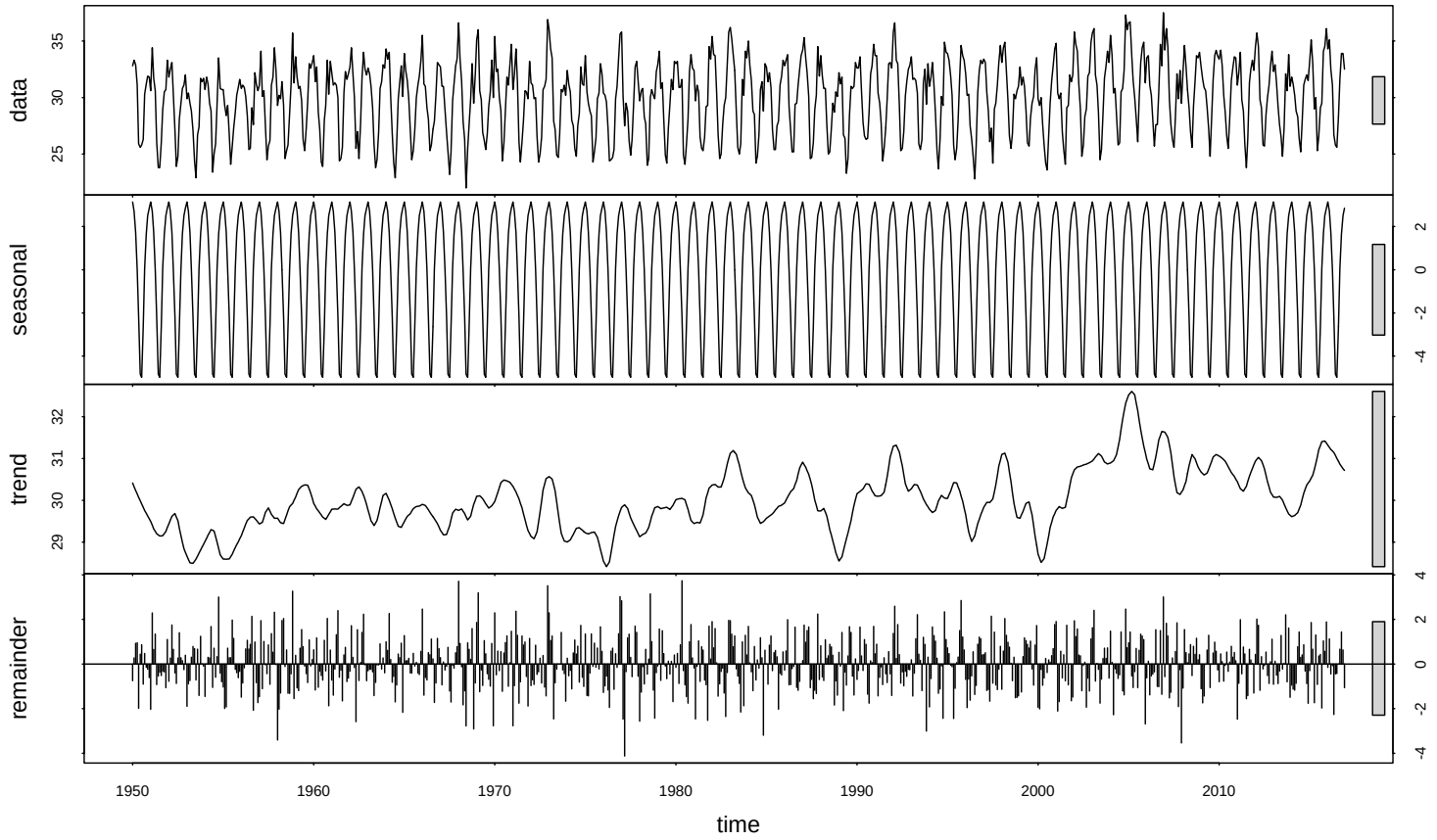


Figure 3.5: Seasonal and trend decomposition of maximum temperatures (°C) per year (1950-2016) for Musina. 'Data' = set of actual values; 'seasonal' component = period; 'trend' = increasing or decreasing direction in the data; and 'remainder' = residual. Data were provided by the South African Weather Service (SAWS).

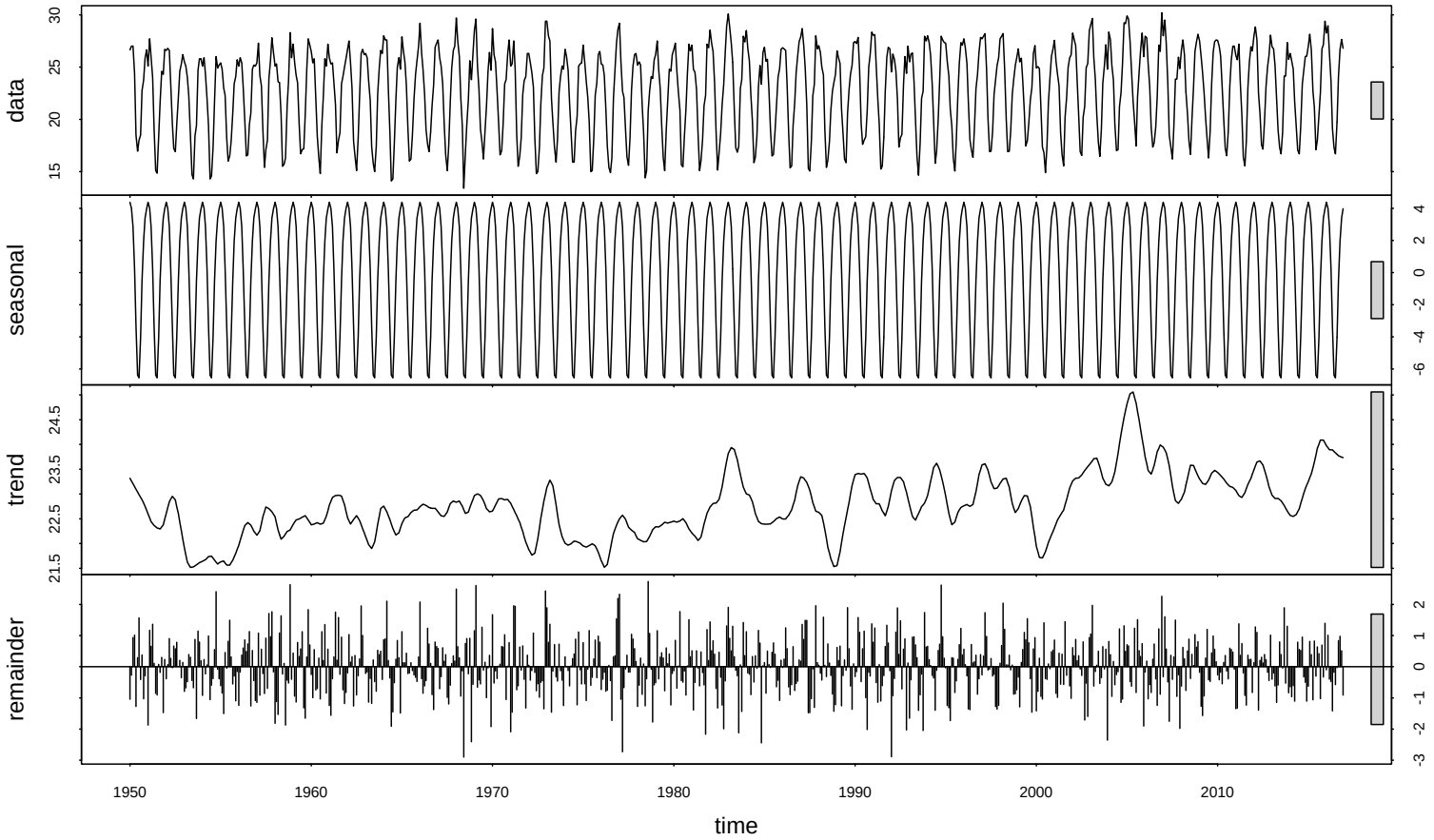


Figure 3.6: Seasonal and trend decomposition of minimum temperature (°C) per year (1950-2016) for Musina. 'Data' = set of actual values; 'seasonal' component = period; 'trend' = increasing or decreasing direction in the data; and 'remainder' = residual. Data were provided by the South African Weather Service (SAWS).

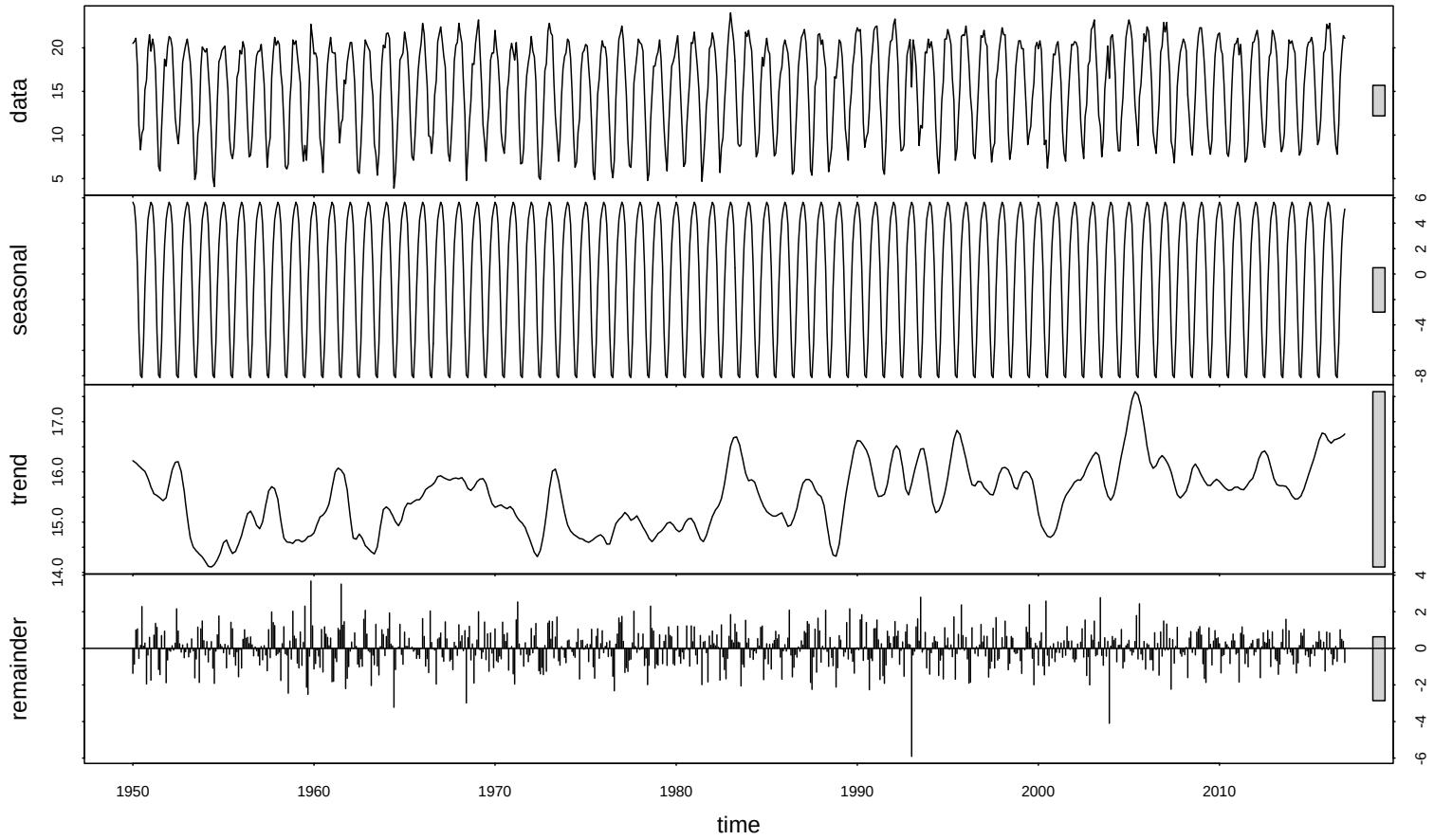


Figure 3.7: Seasonal and trend decomposition of minimum temperature (°C) per year (1950-2016) for Musina. 'Data' = set of actual values; 'seasonal' component = period, 'trend' = increasing or decreasing direction in the data; and 'reminder' = residual. Data were provided by the South African Weather Service (SAWS).

3.4.2. Heat waves trends

Based on the average maximum temperature for the hottest month (January), the value for determining the threshold for a heat wave in Musina was 38.9ºC (that is 33.9ºC + 5ºC). The rate of increase in the number of heat wave occurrences per annum was at +0.066 days year^{-1} for the study period (see Fig. 3.8). The frequency of heatwaves for the period 1950-1986 was ~1.5 year^{-1}, while that for the period 1980-2016 was ~3.1 year^{-1}. Further, the mean duration of heatwaves has increased considerably in the last three decades (mean = *5.9* days) over those of the previous decades (mean = *4.6* days).

3.4.3. Relative humidity trends

Time series trends for relative humidity over the period 1980-2016 are shown in Figure 3.9. Relative humidity ranged between 10% during winter (July) of 1980, and 83.2% during Autumn (April) of 2012. Data indicate a positive relative humidity trend (+0.06% year^{-1}), albeit not statistically significant (P = 0.3) for the period 1980-2016. Generally, summers had the highest relative humidity measurements (mean = 46.8%) and winters the lowest (mean = 36.3%).

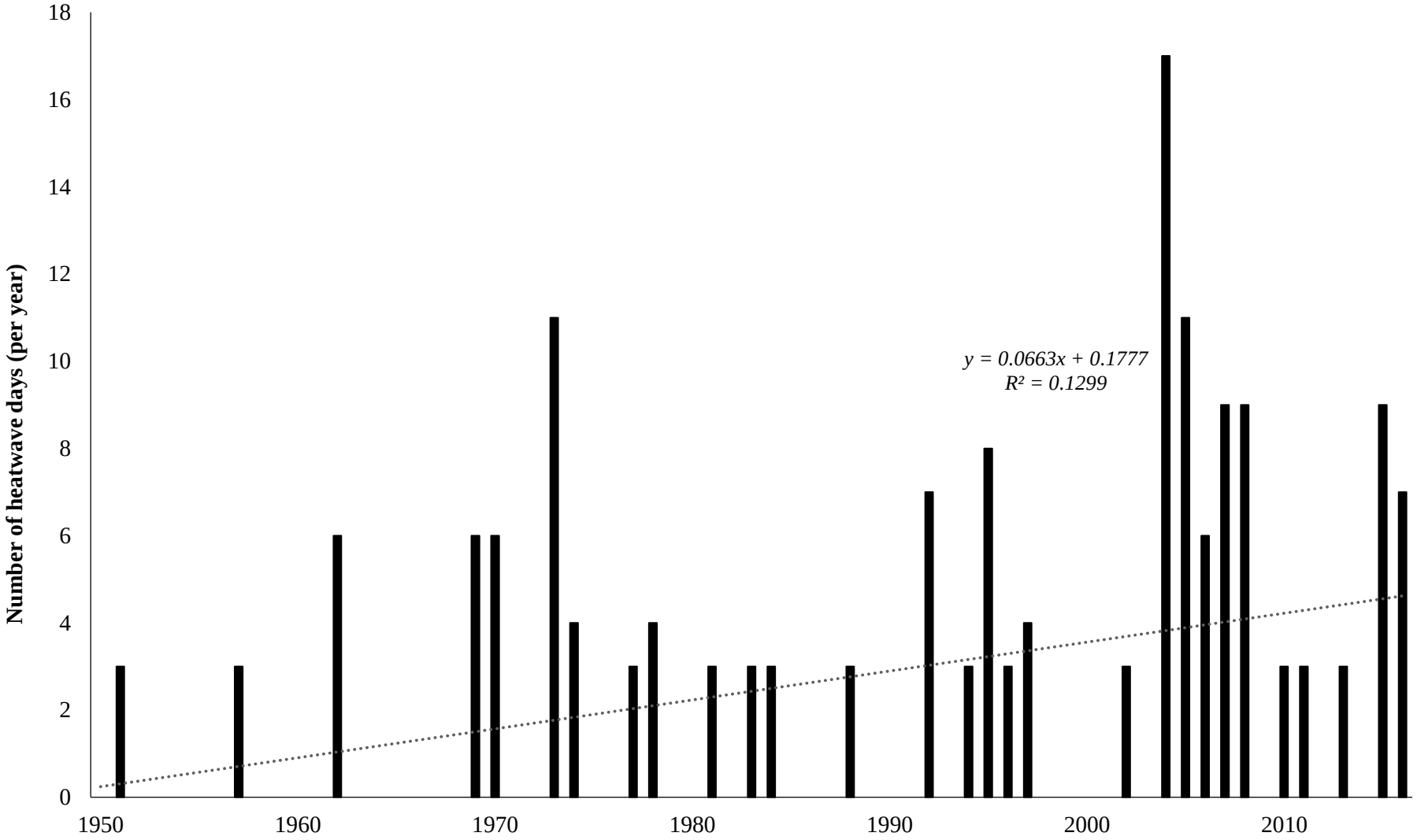


Figure 3.8: Number of heat wave days in Musina, plotted per year for the period 1950-2016. Based on the average maximum temperature for the hottest month (January), the value for determining the threshold for a heat wave in Musina was 38.9ºC (that is 33.9ºC + 5ºC). Data were provided by the South African Weather Service (SAWS).

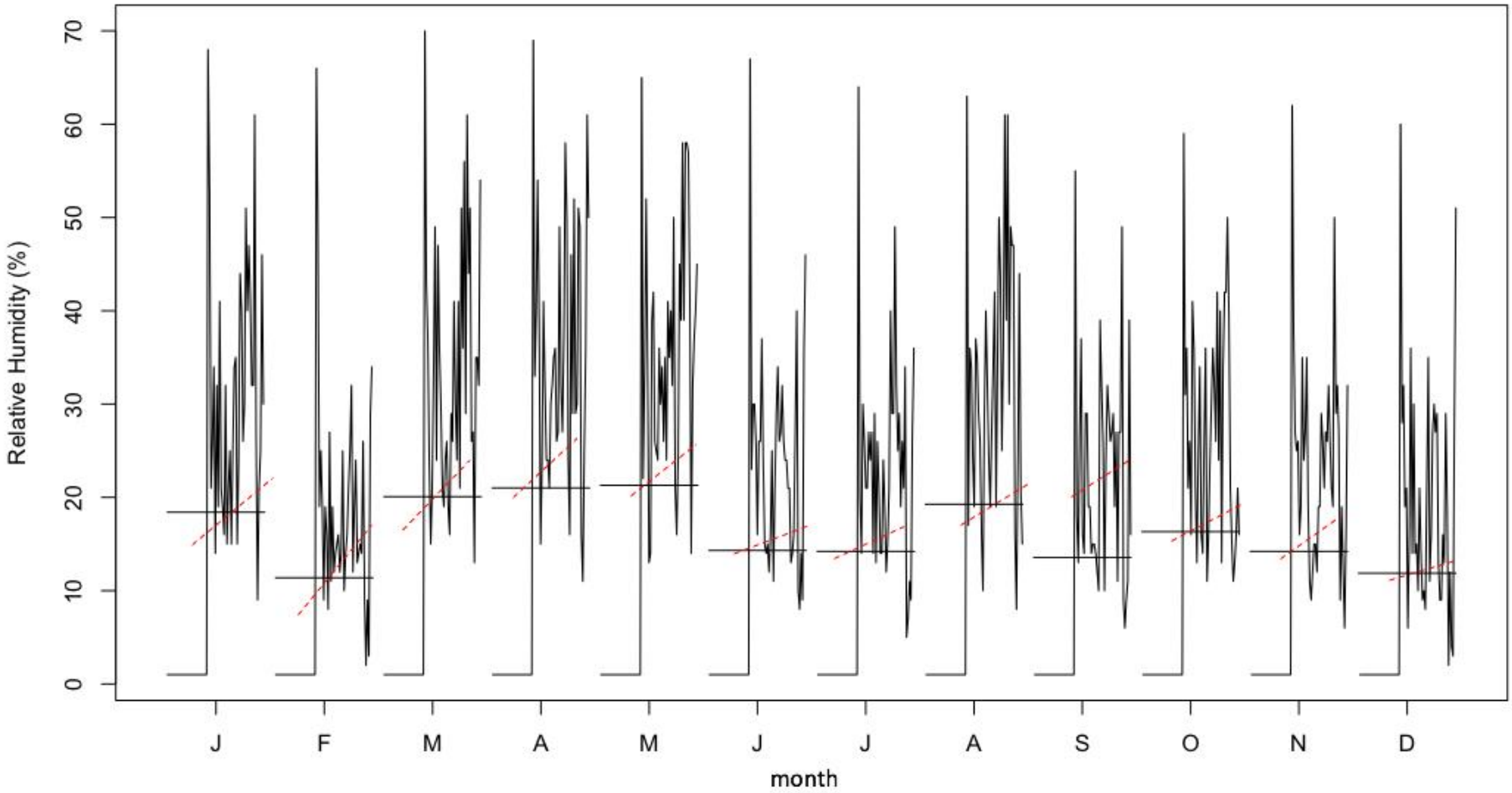


Figure 3.9: Mean monthly relative humidity trends per year (1950-2016) for Musina. Horizontal lines = monthly mean values / red dotted lines = trend lines. Data were provided by the South African Weather Service (SAWS).

3.4.4. Variability in temperature and relative humidity

Seasonal probability density plots for temperatures and relative humidity in Musina (1980-2016) are presented in Figure 3.10. Weather parameters across all seasons had low probability densities (below 50%), implying high variability. It is noteworthy that probability densities of relative humidity across all seasons were always very low (that is less than 10%), with considerable inter-annual and decadal variability. The period 2010-2016 presented the highest variations, with probability densities of <0.5% for relative humidity and <5% for minimum temperatures. Relative humidity was the least predictable weather variable across seasons for the study period.

Summer average temperatures across all decades were significantly ($P = 0.03$) more predictable (~50%) than other temperature parameters during summer, as well as other seasons. The predictability of minimum temperatures was ~40% for summer, which was stronger than maximum temperatures that had a probability density of ~25% during the same season. Autumn, winter and spring were less predictable for all temperatures compared to summer. The only exceptions were prediction for autumn maximum temperatures over the decades 2000-2009 and 2010-2016, both having probability densities of ~25%, a value which exceeded the summer percentages.

3.4.5. Heat Index

Heat index values were estimated for the period 1980-2016, based on the availability of relative humidity (and temperature) data, using weathermetrics. According to the seasonal and trend decomposition time series graph (see Fig. 3.11), the heat index trend ranged between 24 and 35°C. The highest heat index (~35°C) measurements were observed during the summer of 2007, and the lowest (~24°C) during winter of 1996. There has been a positive

trend (that is +0.03°C year^{-1}) in the heat index over the last three decades.

3.5 Discussion

There is compelling evidence for a warming trend in Musina. Maximum temperatures record a higher rate of increase (+0.03°C year^{-1}), compared to minimum temperatures (0.025°C year^{-1}), a finding consistent with what other studies in the region and globally have demonstrated (for example Easterling et al., 1997; Kruger and Sekele, 2013; MacKellar et al., 2014; Keggenhoff et al., 2015; Davis et al., 2016). However, the tendency for stronger increases in maximum rather than minimum temperature indices is inconsistent with other global warming reports, which have shown a decreasing diurnal temperature range (DTR) due to minimum temperatures increasing at a faster rate than maximum temperatures (Karl et al. 1993; Easterling et al., 1997; Liu et al. 2004; Blunden and Arndt 2012). DTR is an important indicator of climate change and is influenced by various spatial and temporal factors, including land use/land cover changes, irrigation, station moves, desertification, and a host of other indirect climatic effects (Qu et al., 2014). Thus, although global perspectives on changes in the climatic system are important, there are complex spatial variations, which necessitate local analysis of trends.

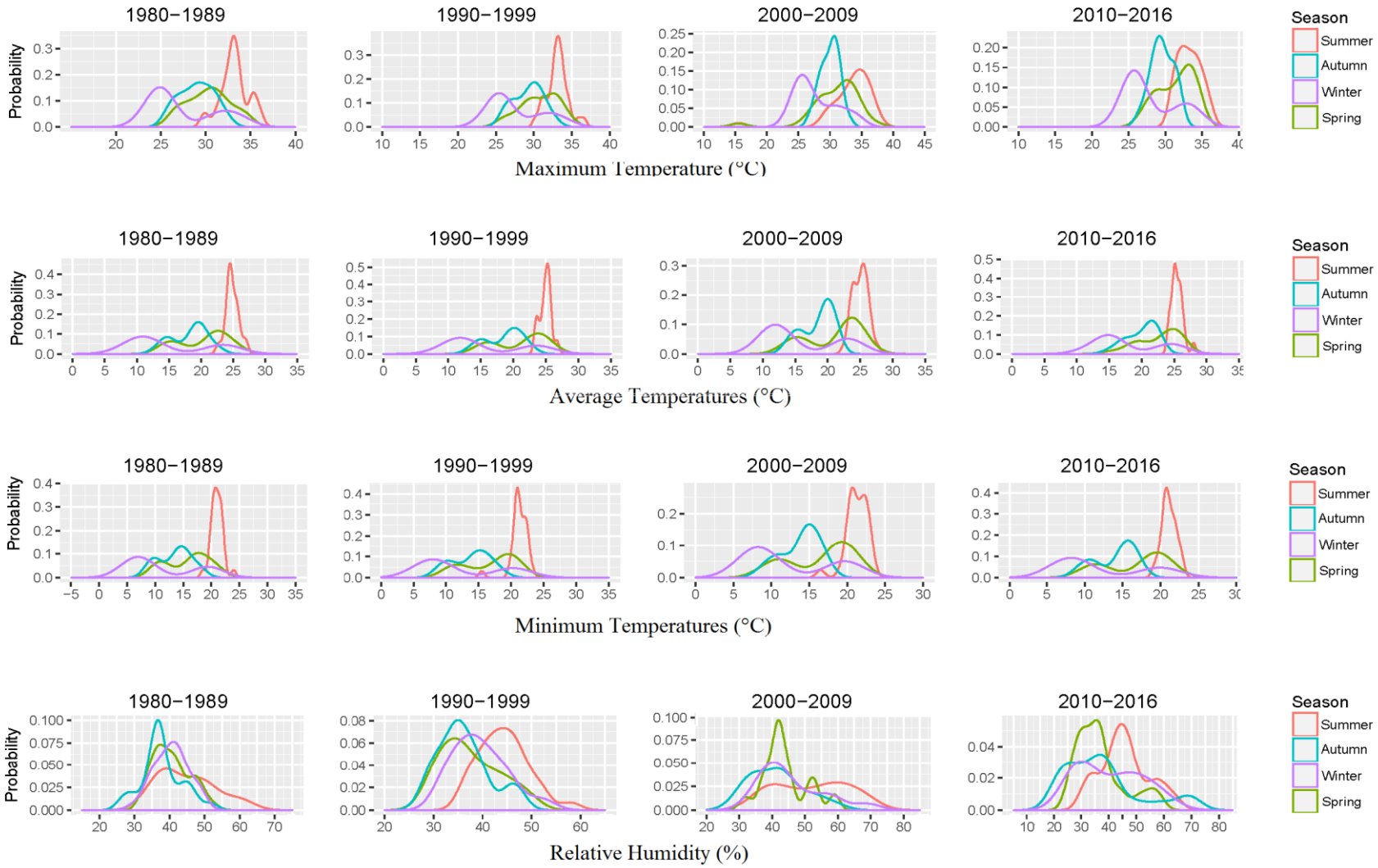


Figure 3.10: Decadal probability densities of seasonal relative humidity and air (that is maximum, average and minimum) trends for the period 1980-2016 in Musina Local Municipality. Probability density plots, to establish variability of relative humidity and air temperature, were calculated using R software package ggplot2.

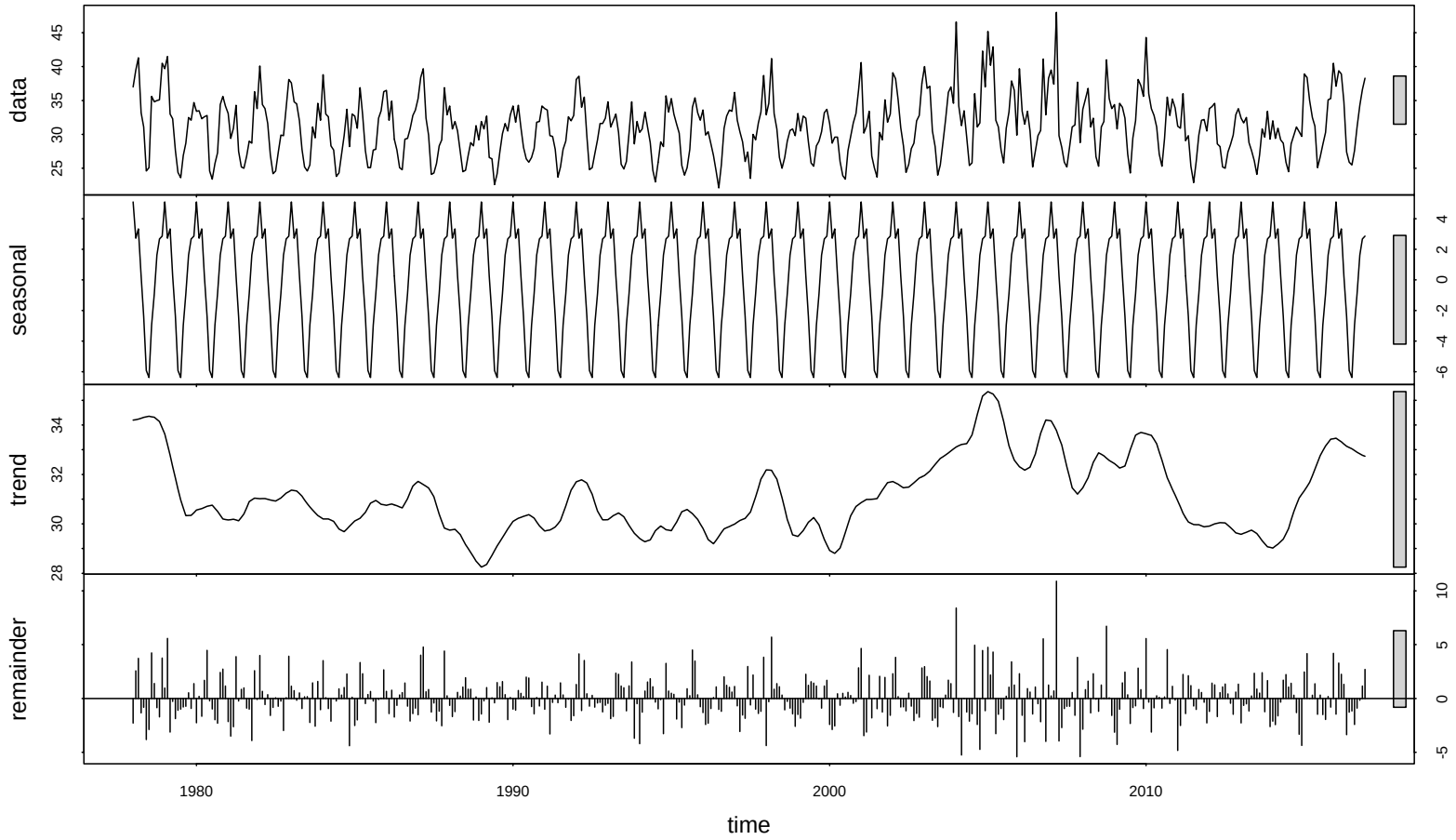


Figure 3.11: Seasonal and trend decomposition of the Heat Index (°C) for Musina: 1950-2016. 'Data' = set of actual values; 'seasonal' component = period; 'trend' = increasing or decreasing direction in the data; and 'remainder' = residual. Data were provided by the South African Weather Service (SAWS).

In Musina, the number of heatwave days has increased and there has been a positive heat index trend, which is consistent with several climatic studies from other regions (Huth et al., 2000; Meehl and Tebaldi, 2004; Department of Environmental Affairs, 2013; IPCC, 2013). Generally, these studies reported an increased frequency of heat waves and hot days both locally (South Africa), and globally, due to accelerated global warming. The main concern with such climatic changes is that they present a potential challenge to sectors such as agriculture, directly and/or indirectly reducing productivity (Schlenker and Roberts, 2009; van der Velde et al., 2012). To this end, the rapid increase in heat wave frequency and intensity in northernmost South Africa poses major concerns for agriculture in an already water-scarce environment, as evaporation rates and water consumption demands likewise increase. Further, high temperatures, especially when combined with high humidity and low air movement, can exceed species-specific threshold levels (or thermal comfort zones), thereby causing heat stress (Lefcourt and Adams 1996). Thus it is likely that farming systems in Musina adversely impacted by climate change, especially in small-scale settings where farmers have limited capacity to adapt. This proposition is in line with findings from an earlier study in Limpopo, which established that although farmers were able to recognize changes in the climatic system, only a few employed some form of adaptation strategies (Gbetibouo, 2009).

Compared to an earlier study in Limpopo (Tshiala et al., 2011), measurements in the current study, which show an extended picture of seasonal variations, demonstrate considerable high variability in temperature and relative humidity (see Fig. 3.10). For sectors such as agriculture, this intricate inter-seasonal, annual and decadal variability presents an unstable environment, making farming a risky business. The high variability of relative humidity may be resulting from an increased inconsistency of rainfall patterns (IPCC, 2013; Ziervogel et

al., 2014). Also, the increased intensity of temperature variability across seasons over the past decades in Musina is consistent with findings from other local studies in the eastern and western parts of South Africa (Kalumba et al., 2013; Davis et al., 2016). Although climatic trends observed in Musina are generally in accordance with other conclusions derived from studies in the southern African region (Tadross et al., 2005; Jury, 2013), which have highlighted a warming trend, there are some evident differences in the rate of temperature increase. For instance, Jury (2013) reports that warming ranged from +0.002°C to +0.045°C $year^{-1}$ in southern Africa for the period 1979-2010, while that for the current study presents warming rates of up to +0.031°C $year^{-1}$ for the period 1980-2016. This variation in findings may be owing to these regional reports being based on climatic models (that is regional climate models and general circulation models which generally have a lower resolution than surface point data), rather than observed data per se. As indicated earlier, although providing change indications that are in accord with past climatic changes, models often have limitations in determining local weather conditions (Tadross et al., 2005; Davis et al., 2016). Besides coarseness in spatial resolution, there are notable differences in output across models used when considered on finer regional scales and over particular periods and seasons of interest (Tadross et al., 2005; Jury, 2013; MacKellar et al., 2014). Thus, it is imperative to test and refine model reports using observed variations to ensure the accuracy of climate change projections. Reconciling climate observations and projections has implications for correctly estimating the potential impact of climate change in a given region, particularly for sectors such as agriculture and tourism.

Climate change research in remote rural areas such as Musina should be on-going, as trends keep changing. Evidence on climatic trends, especially at local level, present a critical basis for governments and other development agencies to build strategic interventions to improve

livelihoods of a target population (Rusticucci and Barrucand, 2004). Farmers may use results from such studies, if appropriately communicated, to understand likely implications of recent climate variations on agricultural production and assist in making more informed farming decisions.

3.6 Conclusion

Climatic conditions in Musina have become more variable in recent decades, consistent with a range of regional and global studies. However, different reports on climate research show that the magnitude of climatic changes varies regionally due to spatial and temporal variations at different localities, which recapitulates/necessitates the significance of downscaled studies on weather conditions. It is likely that observed climatic trends at localized levels adversely affect the agricultural sector, especially in small-scale farming systems where farmers have limited adaptive capacities. Analyses of local weather conditions constitute an important information base for understanding agricultural performance in an area, as the local climate has direct and indirect effects on productivity. Scientific research in the region should seek to establish the impact of climate changes and variability on specific small-scale farming systems and enterprises, and consider relevant downscaled adaptation options

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CHAPTER 4

4.0 Perspectives on the impact of climate change on rural poultry production in South Africa: a case study of Limpopo Province

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(Submitted for publication in the Regional Environmental Change)

4.1 Abstract

Rural households in many developing countries contend with multiple challenges, including a lack of resources, food insecurity, and poverty. Climate change threatens to compound existing challenges. Small-holder farming is particularly vulnerable to climate change due to limited adaptive capacity. This study sought to establish farmers' perspectives on the likely impact of climate change on their rural poultry. A baseline questionnaire-based study was conducted across 106 households in Musina. Most households lacked reliable and adequate sources of income and, for example, had days when they had to skip meals as a coping strategy. With such poverty, coupled with poor access to scientific information on agricultural production, the farmers' adaptive capacity to shocks such as climate change is likely to be limited. All farmers appreciated poultry's contribution to food security and income generation, yet rural poultry was given little attention in terms of inputs. A reduction in poultry productivity in recent years coinciding with increased ambient temperatures was reported. However, no clear predictions were made regarding impacts that increased warming may have on growth and development of birds in general. Rather, farmers perceived their poultry as hardy and well adapted to survive any changes in climate that may occur in the future.

Key words: heat stress; household; productivity; warming; village chickens

4.2 Introduction

Subsistence and small-holder farmers usually produce crops and rear livestock with minimal inputs. Such practices significantly contribute to the alleviation of poverty in rural areas of most low-income countries (Hachigonta et al., 2013; Mapfumo et al., 2014). Although small-holder farming is estimated to contribute 60 – 66% of food consumed in sub-Saharan Africa (Mapfumo et al., 2014), agricultural productivity remains low across the continent, resulting in low incomes, poverty and food insecurity (Hachigonta et al., 2013). Observed and projected changes in climate further threaten to impede this agricultural sub-sector.

Analyses of the impacts of climate change suggest that small-holder farmers are inherently vulnerable to climate change, as they depend on the natural climate and resources for production (Shisanya and Mafongoya, 2016). A number of regions globally have experienced increases in ambient temperatures over the past few decades (Hachigonta et al., 2013; Cattaneo and Peri, 2016; Furlong and Zalucki, 2017). Ongoing temperature increases, in the range of 4 - 6°C, are anticipated for southern Africa by 2100, which is higher than that indicated by global mean projections (Department of Environmental Affairs, 2013; Stocker, 2013), implying that heat stress may be particularly severe in southern Africa. Further, incidences of heat stress for many arid and semi-arid regions are likely to be exacerbated by the predicted decrease in rainfall and increased incidences of droughts and dry spells (Engelbrecht et al., 2015).

In South Africa, based on socio-economic status, provinces highly vulnerable to climate change include Limpopo, KwaZulu-Natal and the Eastern Cape (Hachigonta et al., 2013). Densely populated rural areas characterize these regions, with a relatively large number of small-holder farmers (Stats SA, 2012; Hachigonta et al., 2013). Performance of small-holder

agriculture in these areas is poor and highly variable, which has been attributed to multiple factors, including a lack of resources (for example land, water) and inputs (for example quality seeds, machinery and technology), poor access, if any, to agricultural extension services (for example technical support) and poverty (Meadows and Hoffman, 2002).

Most small-holder farmers in rural areas of developing countries rear poultry, especially village chickens, as a side-line activity (Kingori et al., 2010; Malatji et al., 2016; Mulualem, 2016; Padhi, 2016). These birds occasionally supplement household protein supply in the form of meat and eggs. They are also considered a delicacy, and may be slaughtered for special guests and functions (that is cultural activities, traditional wedding ceremonies). In cases where cash is urgently required, rural poultry is particularly valuable, as chickens are relatively easy to sell compared to other livestock, such as cattle (Nyoni and Masika, 2012).

Despite the essential role that poultry plays in rural households, several challenges, such as predation, theft, and disease may impede production (Mulualem, 2016; Malatji et al., 2016). Climate change may also aggravate existing challenges (Chishakwe, 2010), yet research on the impacts that climate change may have on rural poultry production remains limited. It is important to establish the small-holder farmers' perspectives on climate change, as it will ultimately influence their willingness to adapt their farming practices. The current study seeks to establish rural farmers' perspectives on the likely impacts climate change may have on poultry production in Limpopo Province, South Africa. Specific objectives include: (i) assessing the importance of rural poultry on rural livelihoods; (ii) determining farmers' perceptions of climate change; and (iii) identifying perceived impacts of historic increases in temperature on rural poultry production.

4.3 Materials and methods

4.3.1. Description study site

Details of the site are given in Section 3.3.1.

4.3.2. Selection of participants and procedure

Following approval from the Human Research Ethics Committee of the University of the Witwatersrand (clearance number H14/11/27), a total of 106 households were selected through purposive and snowballing sampling techniques. Only individuals who owned poultry and were willing to participate were considered. A cross-sectional questionnaire survey was used to establish the perceived relationship between climate change and rural poultry production. The questionnaire (refer to Appendix A) was translated into Venda by native speakers, and then translated back into English, to ensure comparability. Pre-testing of the survey instrument took place in Madimbo in November 2014. Questionnaire-based structured interviews were conducted at various levels, including households, key informants in the villages (village heads), and agricultural extension officers at a district level.

4.3.3. Statistical analyses

Data collected was analyzed using the Statistical Analysis Software (SAS) (Delwiche and Slaughter, 2012). Descriptive statistics regarding demography of participants, rural poultry dynamics, management practices etc. were computed as percentages using Proc FREQ (frequencies). The median and interquartile range were used to show the centre of the distribution of poultry flocks, eggs laid and clutches per household.

4.4 Results

4.4.1. Village chickens

All identified households approached were willing to participate in the study. The majority of household heads were male (59%), married (65%) and literate (71%). Literacy was defined as the ability to read and communicate in writing. Education levels varied, with 40% having received secondary education.

Despite a wide range of income generating activities, many of the participants (48%) had no formal employment. Very few interviewees were full-time farmers, with most participants (77%) farming on a part-time basis. Government grants and remittances from off-site relatives contributed significantly to household incomes. A few (18%) households had some dependents (family members) living in the Musina Local Municipality town and nearby farms. Most members of the family were healthy, with no known chronic illnesses (93%) or disabilities (97%). Most households included able-bodied family members fit to work in agriculture-related operations (crop/livestock management). Although most farmers had adequate access to food, some households (11%) faced difficulties in securing meals, and some (8%) went without a meal for an entire day on occasion.

4.4.2. Rural poultry flock dynamics and perceived changes

All farmers in this study owned poultry, predominantly village chickens, with ~10 birds per household (with an interquartile range of 8-17 birds). Chickens were kept for consumption (egg and meat), and occasionally sold to generate petty cash. The price obtained per bird was ~R50 (~US$3.91), but prices ranged from R30 – R80, depending on size and financial need at hand. Although some farmers considered breed (28%) and colour (20%) when selecting

chickens for breeding stock, most (52%) were interested in bird size, which would enhance consumption quantity and selling price.

In addition to poultry, 38% of farmers owned cattle, 30% owned sheep, 59% owned goats, 26% owned donkeys and 28% owned pigs. Cattle, sheep, and goats were valued more than chickens, mostly based on the income generated per livestock unit when sold. Numbers (herd size) of cattle, goats, and sheep were reported to have decreased by 40-50% over the past ~10 years, mostly attributed to disease and drought-related mortalities. In contrast, village chicken production was reported to have declined by 20-30% over the same period. Perceived changes in chicken productivity included delayed point of lay (47%), reduced number of eggs laid per clutch (54%), decreased clutches per year (54%), reduced hatchability (41%), reduced chick survival to maturity (42%), reduced bird sizes (44%), as well as reduced flock size (71%). Some farmers (45%) also alleged that the seasonal reproductive behaviours of birds had changed. In particular, it was highlighted that the laying routine had changed, with chickens now having a single clutch instead of two over the summer season.

Respondents reported that each hen laid ~60 eggs in ~5 clutches per year, with ~12eggs per clutch. Farmers consumed about 20% of eggs per clutch at most and assigned the majority for incubation. Hatchability, as a proportion of eggs not consumed, was at 67% (that is 8 eggs out of 12) of which about four birds survived to maturity. Chick losses reported were related to predation, theft and other unknown causes. Predators, such as hawks, were perceived to target chicks and growers, while adult birds were vulnerable to local theft. Despite these losses, 75% of farmers claimed that village chicken production was economically beneficial to them. Increases in the size of poultry flocks were attributed to hatchings (89%), gifts from relatives and neighbours (5%), purchases (4%) and loans from relatives and neighbours (2%),

while decreases in the size of poultry flocks were attributed to mortalities related to diseases (15%) and predation (28%), household consumption (33%), sales (14%), gifts to relatives (6%), loans to relatives and neighbours (3%) and theft (1%).

4.4.3. Housing, feeding and health care

A large number of respondents (59%) indicated that they supplied housing for their flocks. Chickens voluntarily sought housing at night, but spent the day scavenging for feed in the local environment. Some birds occasionally used chicken houses (that is seeking shades) as buffers against hot weather, however, housing mainly functioned as security against theft and predation at night. Structures were all roofed, the sides mostly (68%) fenced, and the natural ground compacted. Most farmers (84%) regularly (approximately 3-4 months) cleaned these structures and use the manure as fertilizer in their home gardens. In cases where shelters were not provided (41%), birds either roosted on trees or remained in open spaces overnight.

Most farmers (72%) provided non-discriminant supplementary feed to their flocks, with no special supplements for birds at different stages of growth. Supplements were provided erratically and varied widely from household to household, but mostly consisted of kitchen waste (primarily leftover starches, 46%). The majority (96%) of farmers also erratically provided tap water (almost daily) in small containers or non-conventional drinkers for chicken consumption.

Health problems were reported to be common to chickens, largely related to both diseases and parasites (55%), however, some farmers stated that they experienced challenges related to diseases only (22%) or parasites only (21%), rather than both. On occasion (48%), these health problems were perceived to have fatal consequences. Many farmers (69%) exercised

some form of control to combat such health challenges. Control methods (as a proportion of farmers that combatted health challenges) were highly varied and included conventional drugs (17%), for example antibiotics (Terramycin soluble powder, oxytetracycline HCL, Pfizer Animal Health), and insecticides (Karbadust dusting powder, carbaryl 5%, Efakto), traditional practices (34%), or a combination of conventional and traditional remedies (49%). Traditional practices (ethno-veterinary control methods) were generally preferred because of affordability (50%), accessibility and availability (29%), as well as perceived effectiveness (18%).

4.4.4. Access to production information

Most farmers had access to agricultural production information (80%). However, access to information relating to livestock markets and prices (11%), and weather information (that is climatic data and seasonal forecasts, 9%) was limited. The three main sources of information were indigenous/traditional knowledge systems (that is engaging relatives and local social networks), media (that is radio, television) and government extension services (Fig. 4.1). Only 18% of the respondents had access to production advice through media and they perceived that most of the information received from conventional channels was neither timely nor reliable. Key informants (village heads and agricultural extension officers) acknowledged that there was limited capacity (that is finances and personnel) for local extension agents to effectively reach every farming household around the Musina villages. Of the farmers that relied on indigenous knowledge systems for decision-making (71%), the majority (62%) relied on traditional leaders and village elders for guidance, while the rest (9%) used their own observations and previous experience to make production decisions.

4.4.5. Environmental changes and temperature trends

All interviewees acknowledged some form of environmental changes over the last three decades or so, with some variations in perceived changes. Perceived changes included increased ambient temperatures, droughts (including erratic and decreased mean rainfall), and decreased vegetation cover (Fig. 4.2). Droughts, reported by 91% of farmers, were identified as a significant challenge for crop production. A third of farmers (34%) acknowledged that climate change would likely impede livestock production in the future, with high ambient temperatures potentially compromising egg-laying (that is quality and quantity) and, ultimately, rural poultry production. However, it is noteworthy that no claims were made regarding previous or current impacts of increased ambient temperatures on rural poultry farming. In fact, most farmers (96%) perceived their birds as hardy and well adapted to survive any extreme weather events.

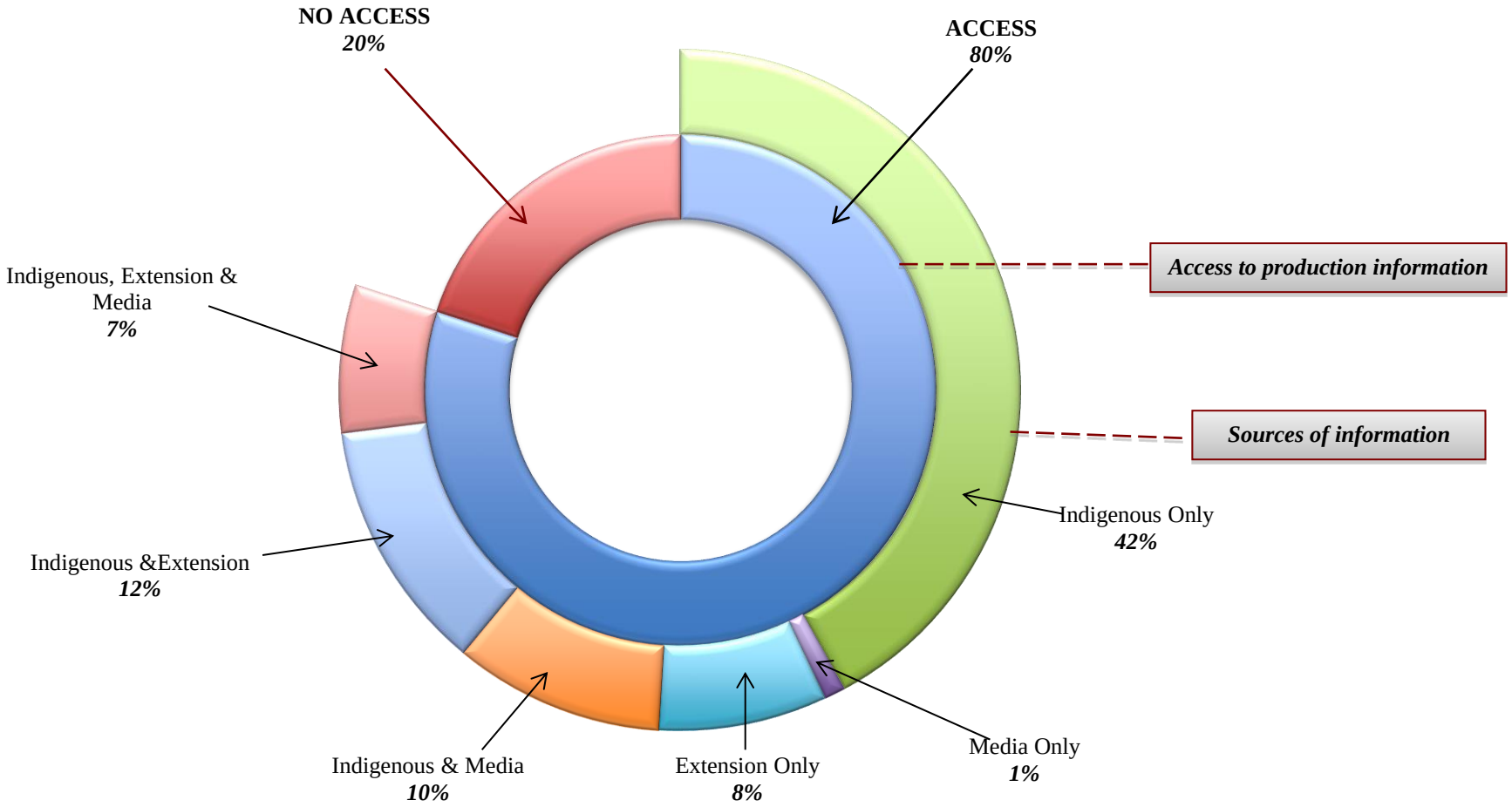


Figure 4.1: Farmers' access to agricultural production information in Musina Local Municipality, Limpopo Province of South Africa. The inner ring shows the proportion of farmers with access to agricultural production information, and the outer ring shows the sources of information. Here: Indigenous = "Indigenous/Traditional knowledge systems", Media = "Radio, Television, Newspapers etc.", Extension = "Agricultural extension officers"

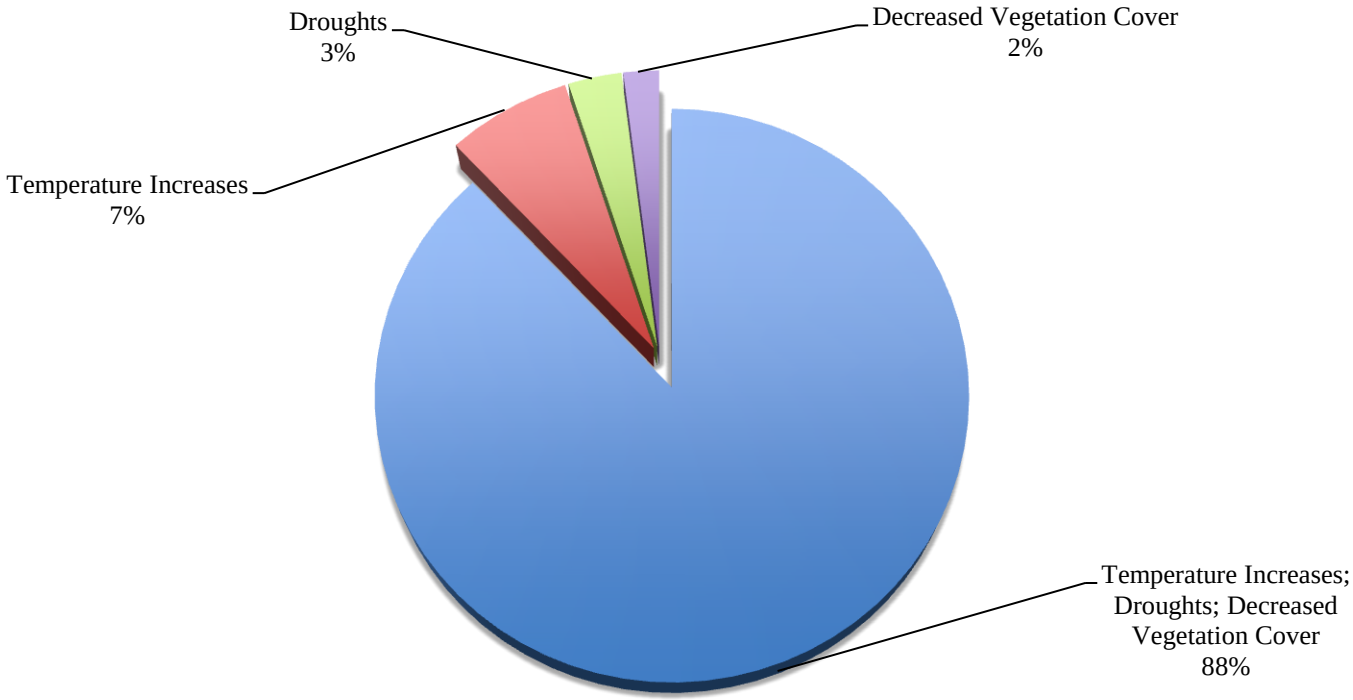


Figure 4.2: Environmental changes over recent decades as perceived by farmers in Musina Local Municipality, Limpopo Province, South Africa

4.5 Discussion

This study is the first to investigate farmer's perceptions of the impact of climate change on rural poultry production. Understanding farmers' perceptions of climate change offers some insights into possible necessary interventions on adaptation strategies (Tambo and Abdoulaye, 2013). The challenge, however, is that farmers' perceptions may vary or easily change within the same area based on personal circumstances or circumstances in the community (Gbetibouo, 2009; Chingala et al., 2017), which in turn may influence production decisions (Bryant et al., 2000). Farmers recognized a decline in rural poultry productivity and a warming climate, however, there was no perceived association between deteriorating poultry productivity and climate change. Several other studies have shown that farmers are aware of the changes in climate and potential impacts on agriculture (Maddison, 2007; Yaro, 2013; Harvey et al., 2014; Chingala et al., 2017). Further, there is some evidence that farmers' perceptions on climate change seem to be aligned to climatic data records (Gbetibouo, 2009; Nyanga et al., 2011). This study focused on farmers' perspectives of the impact of climate change on rural poultry production.

Farmers highlighted the importance of rural poultry in their livelihoods as a source of food and income (occasionally), a report consistent with earlier studies (Kingori et al., 2010; Nyoni and Masika, 2012; Mwacharo et al., 2013; Malatji et al., 2016). However, rural poultry farming in Limpopo (one of the poorest provinces in South Africa), as in many regions across Africa (Yemane et al., 2013; Yusuf et al., 2014; Malatji et al., 2016), faces a range of challenges, as mentioned previously. Some of the major production challenges relate to management practices (Muchadeyi et al., 2004).

Rural poultry, predominantly village chickens, are usually kept by resource-limited farmers and raised with minimum input in terms of feed, housing and general health care (Acamovic et al., 2005; Aboe et al., 2006). These birds mostly scavenge for feed in the local environment to meet nutritional needs. Under scavenging systems, birds are susceptible to predation and theft (Kusina et al., 2001; Pickworth and Morishita, 2007; Biswas et al., 2008), which may explain the relatively high predation-related losses reported by farmers. However, incidences of theft seemed low in the current study, unlike reports from Zimbabwe (Kusina et al., 2001; Muchadeyi et al., 2004), Malaysia (Soleimani et al., 2011), Ethiopia (Yemane et al., 2013; Mulualem, 2016) and other regions within South Africa (Nyoni and Masika, 2012; Malatji et al., 2016). Theft-related losses may, however, increase with the increased demand for food (Tariq et al., 2014) likely to occur in poor communities like Musina.

In addition to predation and theft-related challenges, scavenging chickens are also prone to disease and parasitic infestation. Contact between flocks of different households, the exchange of birds as gifts or loans, sales and purchases are key sources of disease transmission (Nyoni, 2011). Because village chickens roam freely in their local environment, there is also a possibility of disease transfer from other domestic fowls and wild birds (Oniye et al. 2001; Acamovic et al., 2005; Nyoni, 2011). Changes in climatic conditions may exacerbate disease risk both through an increase in the prevalence of particular diseases, and as a result of disease vectors and parasites establishing themselves in new regions (Gale et al., 2009; Semenza and Menne, 2009). Such indirect effects of climate change are likely to confound the direct effects of increased ambient temperature exacerbating heat stress of rural poultry (Lara and Rostagno, 2013).

Heat stress reduces feed intake, compromises growth and development, and causes mortality, and is thus considered the most important bioclimatic factor that impedes productivity in poultry (Thornton et al., 2009). Ambient temperatures in Musina frequently exceed 30°C, a temperature known to cause heat stress in commercial breeds (Yahav et al., 1995; Tankson et al., 2001; Ilori et al., 2012; Ziervogel et al., 2014). By scavenging outdoors, village chickens are exposed to these high ambient temperatures, and may have acclimatized to these conditions (Soleimani et al., 2011), which supports the anecdotal evidence of village chickens being "hardy". Commercial chickens have been bred for a high feed conversion ratio, which correlates with vulnerability to heat stress (Soleimani and Zulkifli, 2010), whereas, through natural selection, local breeds may possess genes and alleles (hereditary characteristics) that are pertinent to their adaptation to local environmental conditions (Romanov et al., 1996; Ngeno et al., 2014). Village chickens, like other indigenous livestock species (Besbes et al., 2007; Mtileni et al., 2012; Ngeno et al., 2014), may represent an important genetic resource that may be better adapted to local conditions than the commercial breeds. However, future climate change will expose chickens to novel environmental conditions which may exceed the adaptive capacity of village chickens.

Farmers reported a 20-30% decline in village chicken production coinciding with increased ambient temperatures and aridity over the last three decades. Perceived changes in poultry production included phenological changes (for example a delayed point of lay and decreased clutches per year), reduced body size of birds, as well as reduced flock size. These responses have so frequently been reported in the literature, that they are now considered universal responses to climate change (Visser et al., 2005; Van Buskirk et al., 2010; Gardner et al., 2011). Additional perceived changes to poultry production included a reduction in the number of eggs laid per clutch, reduced hatchability of eggs and reduced survival of chick to

maturity. Because ambient temperatures directly influence growth and development of birds (Mwale and Masika, 2009; Lara and Rostagno, 2013), it is likely that these responses are the consequence of recently increased temperatures. Yet the farmers never explicitly linked the perceived changes in poultry production with climate change. This disconnect could have been due to their (farmers') low levels of education.

A third of the farmers acknowledged that future increases in ambient temperatures may compromise egg-laying (that is quality and quantity). Heat stress does indeed have detrimental effects on egg production and leads to a decrease in egg quality (Lara and Rostagno, 2013). For example, under conditions of heat stress, eggshell mineralization may be compromised owing to decreased plasma calcium and respiratory alkalosis (Lin et al., 2004). Dietary supplements may prevent a decline in egg quality associated with heat stress (for example see Chung et al., 2005), yet rural farmers have limited recourses to invest in dietary supplements.

Farmers' input in village chicken production is directly linked to the capacity of farmers to absorb external shocks. Analysing different dimensions of assets (natural, physical, human, social or financial) available to a household explicitly exposes the relationship between household wealth and vulnerability to a given shock, such as climate change (Mapfumo et al., 2013). In the current study, most farmers were poor, barely affording daily meals for their households. Thus, farmers are likely to be vulnerable to climate-related shocks since they lack the financial capacity to implement coping strategies (for example supplementary feeding). The vulnerability of farmers is also a function of access to information related to agriculture and relevant weather events (Dutta, 2009; Ferris et al., 2014). Lack of adequate agricultural information is common in most rural settings, especially in developing countries

with limited investments in terms of local agricultural extension agents. As evident in this study, and others (Dutta, 2009), traditional (or local) knowledge systems tend to serve as a core part of rural farming in developing communities. However, information received from local knowledge and network systems may vary within the same community, indicating unequal access to, or possibly distorted, information (Dutta, 2009). Further, future impacts of climate change are likely to present adaptation demands that are beyond the scope of current local knowledge systems (Mapfumo et al., 2014). Thus, the use of indigenous/traditional knowledge systems may be limited in dealing with novel challenges (for example heat stress and novel diseases and parasites) that come with climate change (Baylis and Githeko, 2006; Thornton et al., 2009), potentially rendering communities vulnerable to climate shocks.

The role of an effective extension service in providing empirical evidence to small-holder farmers is critical for increasing agricultural productivity and food security in rural areas (Benjamin et al., 2016). Most farmers (~62%) in the current study had limited access to conventional agricultural production information and those that had, had little confidence in the information channels as a result of a perceived lack of credibility. Active involvement of farmers in scientific research and development of relevant approaches within communities has the potential to enhance uptake of agricultural and climate adaptation options meant to improve agricultural productivity (Mapfumo et al., 2013). Such an approach also provides an opportunity for farmers and researchers to integrate local knowledge systems with new technologies and establish best adaptation options under an unknown future.

4.6 Conclusion

It is likely that rural poultry in southern Africa will increasingly be adversely affected by heat stress. However, no cases were made regarding impacts that increased warming may have on

growth and development of birds in general. Despite most farmers reporting a reduction in productivity over a period in which warming occurred, the general perception was that rural poultry is “hardy” enough to cope with projected ambient temperature increases. Empirical evidence correlating warming of the climatic system and rural poultry production is still limited and requires additional research. Further, agricultural extension technical support would be critical in helping farmers understand intricate climate change-related challenges and opportunities for improving rural poultry farming.

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CHAPTER 5

5.0 Seasonal flock dynamics and management: characterizing village chicken production in South Africa

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5.1 Abstract

Village chickens play a significant role in the lives of many resource-limited rural communities, yet these farmers face challenges in poultry production that may compromise the benefits derived from this agricultural enterprise. In order to improve village chicken production, it is essential to first understand flock dynamics and management practices. This study characterizes village chicken production in one of the poorest communities in Limpopo Province, South Africa. A total of thirty households from four villages in Musina Local Municipality, selected purposively, participated in this monitoring study from February 2015 to January 2016. Flock entries constituted mainly hatchlings, and a few gifts and purchases. Village chickens were mainly kept for family consumption and sold occasionally for income generation. Most flock exits (57%) are, however, in the form of losses (that is mortalities, theft etc.). Mortalities were suspected to be health-related, a result of predation or other unknown causes. Most suspected health-related mortalities were associated with parasitic infestations, which were commonly treated using traditional remedies. Predation, one of the major contributors of losses (19%), was a challenge for chicks and growers during the day when chickens were scavenging for feed. Such losses could be reduced by improvements in the provision of feed, and confinement of younger birds to chicken housing structures. Provision of secure shelter at night could also protect adult birds from theft, which accounted for 17% of losses. Such interventions in the area of feeding and housing will, however,

require financial and technical capacity. Future agricultural extension support will be essential in improving the contribution of village chickens to the livelihood of rural farmers. Further, research should focus on the effects of climate change on village chicken production as these may compound existing challenges.

Key words: indigenous, local, village, poultry, rural, traditional, scavenging, subsistence

5.2 Introduction

Over the past two decades or so, research has shown the value of poultry in rural areas of developing countries (for example Kitalyi, 1998; Mack et al., 2005; Moreki, 2010; Malatji et al., 2016). Poultry species such as chickens, ducks, geese, guinea fowls, quails and pigeons play a range of significant roles in the lives of many resource-limited rural communities. Rural poultry is primarily used for consumption (meat and eggs), and generation of family income (sales and barter trade) on occasion but may be also used to strengthen local social networks when used for rituals, cultural activities and as gifts.

Village chickens, also referred to as rural, backyard, indigenous, scavenging, traditional, local, native or family chickens (Moreki, 2010), are the predominant poultry species in most rural communities of developing countries. These birds thrive with limited inputs from rearers, making the best use of locally available resources in terms of feed and shelter. As a result of poor input investments in this production system, productivity is usually very low compared to commercial production systems (Yusuf et al., 2014). For example, layers produce an egg every 25–26 hours in the commercial sector, while village chickens may lay one egg every 2 to 3 days (Nebiyu et al., 2013). Other common production challenges include an inherent low reproductive performance (for example late maturity), poor nutrition, limited

housing and high losses related to predation and health related mortalities (Gondwe and Wollny, 2007; Yemane et al., 2013; Yusuf et al., 2014; Malatji et al., 2016).

To meet their nutritional requirements for growth and development, village chickens scavenge for feed. Although farmers occasionally supplement feed with grains and kitchen wastes or leftovers, the process is generally erratic and indiscriminate, and birds at different stages of growth (that is chicks, growers and adults) compete for the same supplements (Muchadeyi et al., 2004; Nyoni and Masika, 2012). Such non-preferential feeding results in weaker groups within the flock, whereby chicks and growers receive sub-optimal nutrition (Tadelle and Ogle, 2001). Further, these birds are likely to suffer from nutrient deficiencies (Sonaiya, 2007), since the availability of feed quality and quantity in the local surrounding environment is not guaranteed.

Scavenging for feed may predispose these chickens to a range of health problems, such as parasite infestations and diseases (Henning et al., 2007). For example, birds may be infected by parasite eggs directly through ingesting contaminated feed, water, and litter, or by eating snails, earthworms and other insects, which become intermediate parasitic hosts or carriers (Butcher and Miles, 2009). In addition, housing structures, if provided, tend to not be well planned and may not protect birds adequately from theft and predation, and in some cases, may even promote diseases and parasitic infestations (Swatson et al., 2002; Malatji et al., 2016). Due to the way poultry is managed in commercial production, such production challenges (for example theft, predation and health problems) are more limited.

In addition to limited management practices, seasonality may also impact rural poultry flock dynamics. Seasonal changes in the availability of resources (such as feed in the local

environment), prevalence of parasites and diseases or weather conditions may influence flock structure and size (Nyoni, 2011; Mapiliyao et al., 2012). For instance, egg production is expected to increase in summer and decrease in winter, as the daylight length changes (Lewis et al., 2010). In order to improve village chicken production (in light of challenges alluded to earlier and in the advent of climate change), especially in poor communities with low adaptive capacities, it is essential to first understand context-specific flock dynamics, and management practices across seasonal environments. There is, however, limited information on seasonal village chicken flock dynamics in resource-limited communities, despite the significant role these birds play in the livelihoods of many rural households, including northern South Africa. In this context, a monitoring study was thus conducted to characterize village chicken production in a seasonal environment, where management options may be constrained due to limited access to resources by financially-strained farmers.

5.3 Methodology

5.3.1. Description of study site

Following a baseline survey (refer to Chapter 3), a monitoring study was conducted to characterize poultry farming in the rural areas of Musina Local Municipality in the Limpopo Province, South Africa. The details of the study site are detailed in Section 3.3.1.

5.3.2. Participants

A total of 30 households were selected among the interviewed farmers through a purposive sampling technique after obtaining approval from the Human Research Ethics Committee of the University of the Witwatersrand (clearance number: H14/11/27). Eligibility was based on willingness to participate and ownership of a minimum of 10 chickens (that is median flock size established from the baseline survey). Further, there had to be a literate member of the

household to facilitate accurate capture of records. All participants were trained and mentored on how to collect data. During weekly site visits, I validated all data inputs provided by farmers.

5.3.3. Description of birds

Although a few farmers in Musina also own other poultry species (for example guinea fowls, quails and pigeons), this study only focused on village chickens. Village chickens were the most numerous and significant poultry species, comprising mainly nondescript breeds, which frequently interacted with other flocks from neighbouring households during scavenging. Village chicken flocks constituted birds of various colours, shapes and sizes, bred from interactions with other flocks from within the villages.

5.3.4. Data collection

Variables recorded included village chicken inventory and reproductive performance. Data were recorded one year (February 2015 – January 2016). Information was collated monthly and seasonally. Seasons in South Africa are divided into summer (December – February), autumn (March - May), winter (June - August), and spring (September - November).

For chicken inventory, both flock entries and exits were monitored weekly. Entries included hatchlings, purchases and possibly gifts, while exits included consumption, sales, mortalities (disease and predation), gifts and theft. Reproductive performance was assessed in terms of age of sexual maturity and egg production parameters. Sexual maturity was calculated as age at first egg production (that is point of lay). Parameters of interest related to egg production included mean egg mass per clutch (clutch = total number of eggs laid per hen per nesting session), clutch size (that is number of eggs laid per clutch) and the number of clutches per

annum. For eggs that were laid in nests provided by farmers and within each participating household yard, I weighed all eggs per clutch to the nearest 0.1g, after hens had completed laying eggs. I also made body mass measurements on a weekly basis for all chickens in each participating household using an automatic mini digital hanging scale (Brand: HTM; Capacity/Accuracy: 50kg/0.005kg; Model number: HT041, China). Birds from 0 – 4 weeks were considered chicks, 5 – 18 weeks as growers, and > 18 weeks as adults.

Management practices such as feeding of birds, provision of shelter and health care, were also captured. For health problems, researchers (in collaboration with farmers) inspected the village chickens for ectoparasites as they monitored body mass. The head, combs, eyelids, wattles, neck, feathers, breast, back, wings, shafts, legs and other external surfaces of the chicken were thoroughly examined for ectoparasites, namely: mites, lice, fleas and ticks. For endoparasites, fresh faecal samples of village chickens around the yards were merely examined with a naked eye early morning. Incidences of watery faecal matter were considered as an indication of the likely presence of endoparasites (Gordon and Jordan, 1982). Assistance acquired by farmers from local agricultural extension services and/or other developmental agencies (related to rural poultry production) was monitored. Data collected on chickens were approved by the Animal Ethics Screening Committee of the University of the Witwatersrand (No. 2015/08/36/B).

5.3.5. Statistical analyses

Statistical Analysis Systems (SAS 9.2) was used for statistical analyses (Delwiche and Slaughter, 2012). The Anderson-Darling and Shapiro-Wilk Test was used to test for normality. Normally distributed variables were then summarized as mean ± SD, while the median and interquartile ranges were used for non-normal variables. Analyses for seasonal

variation in egg production (for example egg mass, clutch sizes etc.) was done using repeated measures of the Kruskal-Wallis test, and the Dunn's multiple comparison procedure was used to pinpoint which seasons were different. Correlations were tested for significance and polynomial regression trendlines were fitted on chick growth curves for each season. Body mass gain was calculated as change in body mass over change in time. Within the same age class, weekly body masses per bird were averaged per season, and the mean ± SD across the birds were calculated. Seasonal variation in body mass was determined using repeated measures of a one-way analysis of variance (ANOVA). Tukey's HSD (honest significant difference) test was then used for multiple comparisons.

5.4 Results

5.4.1. Flock inventory

Each farmer owned 15 village chickens on average, with an interquartile range of 11-18. Flock entries constituted mostly hatchlings, gifts and a few purchases (Table 5.1). Incidences of purchases were observed in isolated cases to assist neighbours and/or relatives in need of cash. Gifts were occasionally received from relatives and neighbours when celebrating achievements or successes, such as childbirth.

Sexual maturity (that is age when hens start laying eggs) ranged between 23 and 33.5 weeks, with an average of 27.5 weeks. Table 5.2 shows seasonal variation of clutch number of clutches per year and number of eggs per clutch, as well as flock structures and flock sizes. Clutches differed seasonal ($P = 0.039$), being largest during the spring and summer seasons. During the summer and spring each hen laid one egg (~40 ± 5g) every 2 – 4 days, while in winter and autumn, hens laid an egg (~38 ± 5g) every 3 – 5 days. Farmers consumed approximately 1 – 2 eggs per clutch. Hatchability, as a percentage of eggs not consumed, was

at 71%; eggs that did not hatch were discarded. Chick survival to maturity, as a percentage of chicks hatched, was 69%. Flock sizes ranged from a low as 13 birds per household in winter, to as high as 28 birds per household in the spring season. Flock sizes varied significantly across seasons between winter and summer and between winter and spring. Across all seasons, chicks made up the majority of the flock, followed by growers, hens and cocks, in that order (see Table 5.2).

Consumption, the main purpose of raising village chickens, only constituted 32% of total exits. Sales contributed 11% of total exits and were made only when farmers were facing two types of scenarios. Firstly, most sales were for generating petty cash in emergencies, and secondly, in a few instances, sales were undertaken when passers-by made offers to purchase for personal consumption. A considerable portion (57%) of total exits was in the form of losses, that is mortalities (suspected health-related and other unknown causes, 21%), predation (19%) and theft (17%). Wild birds (hawks and kites) were reportedly responsible for most of the predator-related mortalities for chicks and growers during the day when chickens were scavenging for feed. However, predation cases were reported by farmers; I did not observe them myself.

5.4.2. Growth and development

The growth curves of chicks per season are presented in Figure 5.1. Body masses for chicks at 4 weeks ranged from as low as 175g (absolute minimum) in winter to as high as 300g (absolute maximum) in summer and spring. Body mass gain was significantly lower in winter (20 g week^{-1}, $P = 0.023$) compared to all other seasons that is spring (53 g week^{-1}, $P = 0.025$), summer (52 g week^{-1}, $P = 0.045$) and autumn (49 g week^{-1}, $P = 0.039$).

Figure 5.2 shows seasonal variation in body masses of growers, hens and cocks. Body masses of growers were significantly different between seasons ($F_{3, 116} = 17.56$, $P = 0.025$), being lighter in winter than in summer ($P = 0.044$). There were also significant differences in seasonal body mass of hens ($F_{3, 86} = 15.91$, $P = 0.017$), with hens being lighter in winter compared to summer ($P = 0.031$) and spring ($P = 0.021$). Similarly, body masses for cocks varied seasonally ($F_{3, 26} = 14.39$, $P = 0.034$), with cocks being lighter in winter than in summer ($P = 0.013$), and spring ($P = 0.041$).

Table 5.1: Seasonal flock entries and exits of village chickens in 30 households of the Musina Local Municipality. Since data was not normally distributed, the median and interquartile ranges (*Q1-Q3*) were used to show seasonal variation.

		Seasons			
		Autumn (Mar – May)	**Winter** (Jun – Aug)	**Spring** (Sep - Nov)	**Summer** (Dec – Feb)
Flock Entries	Purchases *(IQR)*	1 *(1-1)*	1 *(1-1)*	1 *(1-2)*	2 *(2-3)*
	Gifts *(IQR)*	1 *(1-1)*	0 *(0)*	1 *(1-1)*	2 *(2-3)*
	Hatchlings *(IQR)*	6 *(5-7)*	5 *(4-6)*	7 *(6-9)*	9 *(8-11)*
	Total Entries	**8 (*7-9*)**	**6 (*5-7*)**	**9 (*7-11*)**	**13 (*11-15*)**
Flock Exits	Sales *(IQR)*	2 *(2-3)*	1 *(1-1)*	2 *(2-3)*	3 *(3-4)*
	Lost/Theft *(IQR)*	1 *(1-1)*	1 *(1-1)*	1 *(1-1)*	2 *(2-3)*
	Predation *(IQR)*	2 *(2;3)*	1 *(1-2)*	2 *(2-3)*	3 *(3-4)*
	Health-related Mortality *(IQR)*	1 *(1-1)*	0 *(0)*	1 *(1-2)*	1 *(1-2)*
	Consumed *(IQR)*	2 *(2-3)*	1 *(1-1)*	2 *(2-3)*	3 *(3-4)*
	Total Exits	**8 (7-10)**	**4 (*1*)**	**8 (*7-10*)**	**12 (*10-15*)**

Table 5.2: Seasonal variation in number of clutches per hen, clutch sizes, and flock structures and total flock size of village chickens per household (in 30 households) within the Musina Local Municipality. Since data was not normally distributed, the median and interquartile ranges (*Q1-Q3*) were used to show seasonal variation.

	Seasons			
	Autumn (Mar – May)	Winter (Jun – Aug)	Spring (Sep - Nov)	Summer (Dec – Feb)
Number of clutches/hen	1 *(1-1)*	1 *(1-1)*	1 *(1-2)*	1 *(1-2)*
Clutch size	8 *(6-10)*	5 *(4-7)*	12 *(9-15)*	11 *(9-13)*
Cocks *(>18 weeks)*	2 *(2-3)*	1 *(1-1)*	3 *(3-4)*	2 *(2-3)*
Hens *(>18 weeks)*	4 *(4-5)*	3 *(2-4)*	6 *(5-8)*	5 *(4-7)*
Growers *(5 – 18 weeks)*	5 *(4-6)*	4 *(3-6)*	7 *(5-9)*	6 *(5-8)*
Chicks *(0 – 4 weeks)*	7 *(6-10)*	6 *(4-7)*	9 *(7-12)*	8 *(6-11)*
Flock size	18 (*17-21*)	16 (*15-19*)	23 (*20-25*)	20 (*19-22*)

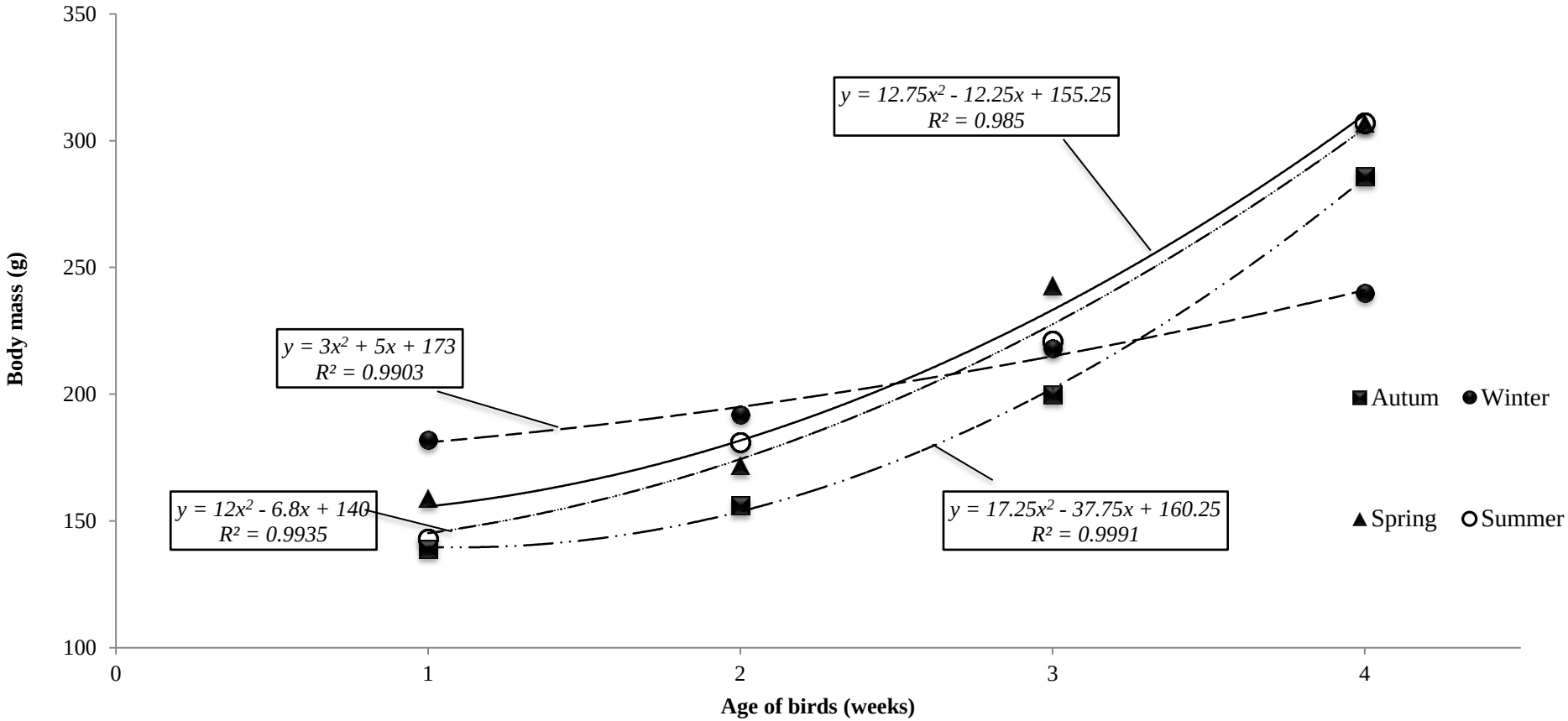


Figure 5.1: Average growth curves of chicks per season. Chick body masses were measured per bird per week for four weeks following hatching in each of the 30 household (with ~7 chicks per household) in Musina Local Municipality, northern South Africa. Correlations were tested for significance, and then polynomial regression trendlines were fitted on chick growth curves for each season.

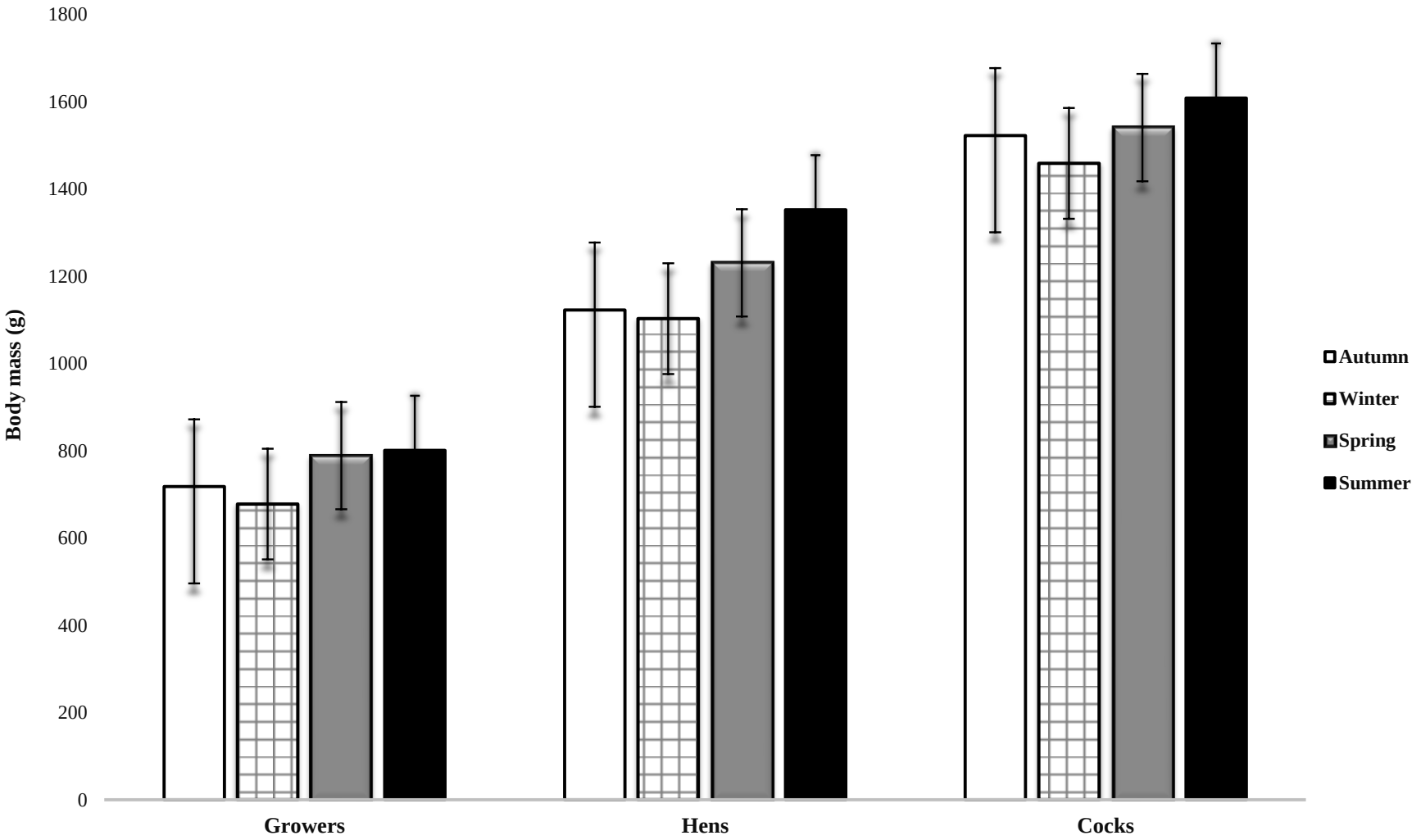


Figure 5.2: Seasonal (that is autumn, winter, spring and summer) average seasonal body masses (mean ± SD) of village chickens measured weekly per bird per age class in 30 household in Musina Local Municipality, northern South Africa. Mean ± SD were calculated across all birds per season for each age class. Age classes of village chickens were categories as follows: *growers = 5 – 18 weeks*; and, *cocks and hens = > 18.*

5.4.3. Feeding and Nutrition

During the day, village chickens scavenged for feed in and around the yard to meet their nutritive requirements. Supplementation of feed was very erratic, and birds could go for several days without being given anything by farmers. Supplements included kitchen wastes, sorghum, maize grain and millet. Some farmers (10%) occasionally provided specific feed (for example pearl millet) to chicks, however supplementation generally was non-discriminant. Quantities given to birds varied from as little as a handful (about 50 g) to about 350 g of grains.

5.4.4. Housing

Birds were mostly housed overnight in structures constructed with corrugated iron sheets, wooden/metal poles and wire mesh (Fig. 5.3). Houses were not standardized and were generally built in a variety of ways, depending on availability of material (corrugated sheets, wire mesh and wood) with the main intention of protecting birds against predators (such as cats and dogs) and theft. A number (53%) of farmers prepared some type of perches or nests for their hens. In 20% of the cases, chickens were left to roost on tree branches overnight. Of roosting flocks, four in five were prone to predation and theft compared to only about two in five incidences in flocks provided with shelter.

5.4.5. Health challenges

For the duration of the study, no specific diseases were observed or reported by farmers. However, ectoparasitic infestations were noted, and these were particularly prevalent over the summer period. Scaly leg mites were common in adult birds of all flocks. Ticks were only identified on the head and the neck regions and attached to the skin under the wings in 61.3% of chickens during summer and 53% of chickens in autumn. Based on observed incidences of

watery diarrhoea within yards of participating households, endoparasitic infestations were also suspected in a considerable percentage of flocks over the spring (33%), summer (68%) and autumn (57%) seasons, but not observed at all during the winter season. However, no reliable diagnosis was made to accurately identify individual parasites.

5.4.6. Health care

Especially during the summer months, farmers would treat their birds for perceived internal and external parasitic infestations. Signs and symptoms such as scratching the body, dullness, fluffed feathers, decreased mobility (translating to reduced scavenging) and watery faecal matter triggered health management actions. Table 5.3 shows typical remedies used in the control of parasites. About 67% of farmers treated their poultry for endoparasites. Specifically, for suspected internal parasite infections, farmers commonly used plants (47%) (*Aloe marlothii and Solanum panduraeforme*) and other locally derived (or traditional) remedies (that is chilli pepper and salt water, 27%), while only 3% of farmers used ESB3 powder (Sulfachloropyrazine 30%), a broad-spectrum oral antibiotic used to treat coccidiosis and specific bacterial diseases in poultry. Only 31% of farmers treated their flocks for external parasites (that is ticks, mites and lice), and the highest proportion (17%) of those households used ash, a traditional remedy. To control external parasites, some farmers (~14%) used a broad-spectrum external insecticide (Karbadust DP, carbaryl 5%), and other insecticides not commonly used on animals (for example Doom Spray (d-phenothrin 0.4%) and Kemprin (Cypermethrin 20%)), which they purchased from the local stores, to control external parasites. Traditional remedies were generally preferred to insecticides and antibiotics because they were locally available, easily accessible and cost-effective.

5.4.7. Extension services

For the duration of this study, there were no extension programs implemented on rural poultry farming in the study area. Some farmers occasionally (that is approximately once a quarter) had contact with government extension services regarding crop production. Village chicken management practices were borrowed or learnt from indigenous traditional knowledge systems shared through local social networks.

5.5 Discussion

To the best of my knowledge, this study is the first to quantitatively examine the composition of village flocks seasonally, and to focus on key production components such as management practices and growth (that is body masses) of birds in rural areas. The current study expands on data collected for my Masters report (Nyoni, 2011) by increasing the temporal resolution of the data (weekly vs monthly visits) and including seasonal body mass measurements. Other studies on seasonal effects on village chicken production (Mammo et al., 2008; Gunya et al., 2014) relied on structured questionnaires (that is periodic surveys), without any seasonal observations and/or measurements. However, quantitative research or empirical investigations are crucial for generation of reliable evidence on seasonal variations.



Figure 5.3: An example of a village chicken housing structure in the villages of Musina Local Municipality, northern South Africa. Housing structures were constructed with corrugated iron sheets, wooden poles and wire mesh. Photo by Njongenhle M. B. Nyoni.

Table 5.3: Remedies used in the control of internal (endoparasites) and external (ectoparasites) parasites, preparation and application methods, target age of chickens, and percentage of farmers using remedies on village chickens in Musina Local Municipality, northern South Africa

Name of remedy	**Type of remedy**	**Preparation method**	**Application method**	**Age/stage targeted**	**(%) Farmers using remedy**
ENDOPARASITES					
Aloe marlothii (Tshikhopha)	Traditional	Leaves are chopped to pieces and soaked in water for about 3 -24 hours to extract the sap. The pieces are then filtered, and water is given to birds for consumption.	Drinking/oral	All	37
Chili pepper	Traditional	Cut to small pieces, and mixed with water with pieces of *Aloe marlothii*	Drinking/oral	Adults	10
Solanum panduraeforme (Mututulwa)	Traditional	The sap of the fruit was added to water for consumption	Drinking/oral	Adults	10
Salt-water solution	Traditional	Salt mixed with water to make a solution *(~40 – 50 grams per litre*)	Drinking/oral	All	7
ESB3 (Sulfachloropyrazine 30%)	Conventional	Dissolved in water for birds to consume	Drinking/oral	All	3
ECTOPARASITES					
White ash (Miora)	Traditional	White ash separated from black ash	Dusting birds	All	17
Doom Spray (d-phenothrin 0.4%)	Insecticide	Purchased ready for use	Spraying birds	Growers & Adults	7
Karbadust (Carbaryl 5%)	Conventional	Purchased ready for use	Dusting birds	All	4
Kemprin (Cypermethrin 20%)	Insecticide	Powder mixed with water as prescribed	Spraying birds	Growers & Adults	3

Across all seasons, management of village chicken production, in terms of housing, feed supplementation and scavenging, remained standard. Reproductive performance of birds (for example body mass), on the other hand, increased over the spring and summer seasons compared to winter (see Fig. 5.1 & 5.2). Flock sizes also varied across seasons and increased over spring and summer (see Table 5.2). Consequently, household consumption and sales also increased over the same period. Changes in productivity of birds (in terms of body mass and egg production) from one season to another could have been linked to changes in availability of feed in the local environment. Spring and summer seasons are usually endowed with abundance of feed resources (for example insects and nutritious parts of plants) (Alders et al., 2009; Kingori et al., 2010; Nyoni, 2011) as birds scavenge to meet their nutritional needs. Thus, to promote the productivity of chickens over the winter season, when feed resources are usually scarce, farmers should consider increasing the quantity of supplementary feeds given to their birds particularly during this period.

Although it is clear that farmers realised some benefits such as protein and income from village chickens, a high proportion of exits in the form of losses due to mortalities, predation and theft define village chicken production in Musina. This finding is consistent with earlier studies (Kusina et al., 2001; Khalafalla et al., 2001; Mapiye et al., 2008; Okeno et al., 2012), which reported that there are high predation and theft-related losses in village chicken production. Most village chicken production systems throughout rural Africa are characterized by limited inputs such as housing, supplementary feed and health care (Kuit et al., 1986; Kusina et al., 2001; Aganga et al., 2003; Muchadeyi et al., 2007; Mapiye et al., 2008; Yusuf et al., 2014). Yet, in spite of their dire poverty and limited resources, farmers in Musina villages invested in their chickens with the majority providing some form of housing, supplementary feed and health care to their chickens. Despite these efforts, farmers suffered

high losses compared to those suffered by farmers in other countries such as Botswana (Aganga et al., 2003) and Zimbabwe (Muchadeyi et al., 2007) through predation and theft.

Since predation-related incidents were mainly associated with chicks, restricting or confining younger birds to housing structures until they are matured enough to manage predator threats could reduce predation related losses (Nyoni, 2011). Maintaining chicks in housing structures to reduce predation would mean that the chicks would need to be fed adequately. Planned feeding or supplementation could improve rural poultry farming output, for example number of eggs produced (Ogle et al., 2004; Muchadeyi et al., 2007; Mapiye et al., 2008; Abidin and Khatoon, 2013) - however, such interventions will require financial resources which farmers in Musina are lacking.

When compared to the commercial sector, number of eggs produced per hen was relatively low, a finding consistent with reports from other rural poultry studies (Muhiye, 2007; Mwale and Masika, 2009). Some eggs laid did not hatch and farmers had no measure in place to assess fertility or predict hatchability beforehand. Candling, one simple and cost-effective management method of assessing fertility of eggs (Cooper, 2001; Borst et al., 2014), could be very useful intervention for farmers in Musina. The candling process involves using a bright light to examine the status of the egg through the shell. Once the fertility status of eggs is established, farmers could consume the infertile eggs, thereby increasing household protein consumption.

Prevalence of diseases and parasitic infestations in village chicken production systems is common (Acavomic et al., 2005; Mwale and Masika, 2011). Scavenging predisposes chickens to a range of infections and infestations (Matur et al., 2010). Further, interaction

with other flocks around the village usually presents a possibility of introducing new diseases and parasites from other infected birds (Nyoni, 2011). In the current study, no diagnoses were done to ascertain prevalence of parasites. However, a recent study on village chickens in Limpopo revealed that almost half of the flocks were infested with endoparasites (Malatji et al., 2016), highlighting the need for farmers to treat their birds for internal parasites.

In general, health care initiatives were more pronounced over the summer season, when parasite loads were perceived to be highest. Health management initiatives against perceived parasitic infestations were locally acquired and erratically applied. This finding is consistent with reports that a considerable number of farmers use traditional methods for treating village chicken diseases and parasites (Mwale and Masika, 2009; Malatji et al., 2016). Knowledge of traditional or indigenous remedies is usually inherited (passed from generation to generation) within families and may or may not be shared with neighbours. Although traditional local remedies are important in rural areas (Tanyanyiwa and Chikwanha, 2011), a major challenge with indigenous knowledge systems is that they may lack supporting evidence as to the extent of their efficacy (Mapfumo et al., 2013). Scientific evidence is critical for effective, efficient and sustainable interventions to address health problems (Nhemachena et al., 2014). Mapfumo et al. (2013) suggested that combining scientific evidence and local traditional remedies the potential to establish sustainable desired outcomes. This collaboration could thus be a viable option to consider in addressing village chicken production challenges.

Government agricultural extension officers should provide rural farmers with scientific knowledge and technical support to improve agricultural productivity (Nyoni and Masika, 2012). However, in the current study, farmers had no access to livestock extension support, a finding consistent with a report by Malatji et al. (2016). Inaccessibility of extension workers

to rural farmers due to the remoteness of some villages, limited resources such as vehicles and/or extension service ratios is a common problem in many developing countries (Mapfumo et al., 2013). Besides limited resources, rural poultry production is not usually part of the scope of the projects supported or targeted by local governments and developmental agency initiatives.

The lack of agricultural extension support or information in this sector may be, in part, a function of a paucity of sufficient scientific information, which consequently forces farmers to only rely on traditional management practices. Appropriate technical programmes derived from the collaboration of all stakeholders such as farmers, local government, research institutions and developmental agencies could enhance the contribution of village chickens to rural livelihoods. Such a coordinated approach could also contribute significantly to food security, nutritional and rural economies (Swatson et al., 2002). However, such initiatives and programmes are still limited and require significantly more support to develop and implement.

5.6 Conclusion

This study has described seasonal variation in village chicken flock composition and outlined management practices employed by resource-limited farmers. It further assessed the reproductive performance (for example body masses and egg production) of village chickens. Despite investing in some form of housing, supplementary feed and health care initiative, farmers suffered considerably high production losses through predation and theft and gained little benefit through consumption and sales. Most production losses occurred in the summer and spring seasons when hatchlings were also highest. It is thus essential that intervention strategies focus on issues related to protection of younger, vulnerable birds. It is further

critical for health management initiatives to be informed by evidence. The role of agriculture extension agents will be central in providing technical support to improve village chicken productivity. Further, since weather conditions are also known to compound challenges in poultry production, there is a clear need for future research that focuses on the impacts of climate change and variability on village chickens, as well as how to mitigate such impacts.

5.7 References

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CHAPTER 6

6.0 How hot is too hot for hardy chickens? Impact of heat stress on village chickens in northern South Africa

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(Submitted for publication in the Poultry Science Journal)

6.1 Abstract

High ambient temperatures may cause heat stress and impose detrimental consequences for chickens, especially in hot regions. As chickens scavenge for feed during the day, they may be exposed to prevailing extreme ambient temperatures. This study examines the impact of high ambient temperatures on village chickens in Musina, northern South Africa. The focus is specifically on the point at which birds begin to behaviourally thermoregulate (that is increased respiratory rates, spread/elevated wings and seeking shade) during the hottest time of the day. Thirty households who owned a minimum of 10 village chickens each, participated in this study. Respiratory rates ($R^2>0.8$), shade-seeking behaviour ($R^2>0.9$) and wing orientation ($R^2>0.9$) of village chickens correlated positively with Wet Bulb Globe Temperature (WBGT) Index. Body mass gain correlation negatively ($R^2= -0.24$) with WBGT Index. In general, it seems that village chickens in Musina are negatively impacted by high environmental temperatures. Hot weather seems to restrict movement of birds and this reduces scavenging, which probably translates to reduced feed intake, and ultimately, retarded body mass gain. Future studies aimed at improving the productivity of village chickens should focus on the impacts of heat stress on egg quality and quantity, as well as intricate interactions between heat stress and other village chicken production challenges.

Key words: climate change, free-ranging, poultry, rural, subsistence

6.2 Introduction

Poultry is particularly sensitive to temperature-associated environmental challenges, especially heat stress (Lara and Rostagno, 2013). Heat stress is an imbalance between the amount of heat produced by the bird and the bird's capacity to dissipate the heat to its surrounding environment resulting from variations of a combination of environmental factors (for example ambient temperature and humidity) and characteristics of the bird (Lara and Rostagno, 2013; Akbarian et al., 2016). High ambient temperatures may cause heat stress in birds, inducing behavioural responses, which may result in detrimental consequences to their productivity, including reduced growth and egg production, decreased poultry and egg quality, and safety (Lara and Rostagno, 2013).

Musina Local Municipality is located in one of the warmest parts of South Africa, which regularly experiences ambient temperatures above 40 °C during warm seasons (Makhado et al., 2016). Such high ambient temperatures are likely to cause heat stress in chickens, as ambient temperatures above 30°C are known to cause heat stress to commercial breeds (specifically broilers), decreasing their feed intake and feed conversion efficiency, and, ultimately, decreasing their production (Tankson et al., 2001). However, in commercial settings, ambient temperatures are usually controlled, and birds are provided with continuous access to feed and water. In contrast, given the scavenging nature of village chickens, it is likely that they are increasingly exposed to high ambient temperatures, and thus placed at risk of heat stress. The village chickens would have to trade off sufficient resource acquisition against heat stress exposure during scavenging. Unfortunately, empirical research on the impact of heat stress on village chickens is still limited. Such a limitation persists despite the fact that these birds play a very significant role, both socio-economically and nutritionally, in the livelihoods of rural communities of developing countries (Nyoni and Masika, 2012;

Nebiyu et al., 2013).

As with other endotherms, chickens will employ behavioural and autonomic mechanisms to counter any change in body temperature and maintain homeostasis (Mustaf et al., 2009; Renaudeau et al., 2012). For example, under high ambient temperatures and heat stress conditions, seeking shade may reduce radiant heat loads and prevent an increase in body temperature, and thereby maintain homeothermy. Chickens may also change the orientation of their wings by elevating them to increase the surface area and promote convective heat transfer to the environment (Gerken et al., 2006; Mack et al., 2013). Birds may also increase their respiratory rates to lose excess body heat evaporatively.

Since these thermoregulatory responses are triggered only when birds are exposed to high ambient temperatures, monitoring the exhibition of related responses in chickens could be useful to determine the extent of vulnerability to heat stress. Further, monitoring body mass gain during hot seasons will be imperative to establish the economic impact of heat stress on village chickens. This study thus examines the impact of high ambient temperatures on village chickens in northern South Africa. Specifically, the focus is to examine correlation of respiratory rates, shade seeking, wing orientation and body mass of birds against high ambient temperatures. In so doing, the study makes a valuable contribution to a broader understanding of the intricate challenges faced in village chicken production. Information on the impact of high ambient temperature on village chickens will also form a critical knowledge base for developing intervention strategies that will improve the productivity of village chickens, especially in impoverished rural communities.

6.3 Materials and methods

This study was conducted over a 13-month period (February 2015-February 2016) so that behavioural observations and body mass gain could be monitored over a range of environmental conditions. Since the focus was on heat stress, no weather measurements were captured during the coldest months (June-August).

6.3.1. Description of study area

The study was carried out in three villages (that is Madimbo, Malale and Domboni) located in Musina Local Municipality in Limpopo Province, South Africa. The details on the description of the site are given in Section 3.3.1.

6.3.2. Village chickens

Thirty representative households (10 from each village) that owned a minimum of 10 village chickens participated in the study. Chicken flocks were composed of three categories of birds, namely cocks, hens and growers at a ratio of 1: 2: 7. Chicks were excluded from this study due to difficulties of conducting behavioural thermoregulation observations in the field. As indicated earlier, birds from 5 – 18 weeks were considered as growers, while adults (that is hens and cocks) were 18 weeks and older. Village chickens were provided with water but tend to rely on scavenging to meet nutritional needs. Supplementary feeding is erratically provided at each farmer's discretion. The birds were monitored in their usual environment, and researchers did not manipulate farmer management practices or local environmental conditions. Clearance to conduct this study was obtained from the Human Research Ethics Committee (clearance number H14/11/27) and the Animal Ethics Screening Committee (No. 2015/08/36/B) of the University of the Witwatersrand, South Africa.

6.3.3. Data collection

i. Climate measurements

Hollow copper globes (150mm diameter), painted matt black, were used as an index of heat stress (Vernon, 1932; Kerslake, 1972). These globes were placed 1 m above the ground in an open unshaded area, in some cases protected by vegetation. Globe temperature measurements were captured using temperature data loggers (Hobo U12-013, Onset Computer Corporation, Pocasset, MA, USA). Globe temperatures have been used to estimate the operative environmental temperature for a range of animals, from bees to cattle (Huey, 1991). Air temperature and relative humidity were measured 1 m above ground using dual channel iButton data loggers (Thermochron Temperature iButton, CAT. N. DSI1922T-F5) housed in a ventilated wind vane (painted white to reflect solar radiation). Data loggers were calibrated individually in an insulated water bath, against a high-accuracy thermometer (Quat 100, Heraeus, Hanau, Germany). Calibration accuracy was better than 0.1°C, and all-weather data were recorded at 30-minute intervals.

ii. The Wet Bulb Globe Temperature (WBGT) Index

The Wet Bulb Globe Temperature (WBGT) Index, a standard index of heat stress, was calculated in a model that takes into account air temperature, black globe temperature, relative humidity (RH), wind speed and barometric pressure. The South African Weather Service (SAWS) provided wind speed and barometric pressure data (2015-2016) for Musina. The WBGT Index was preferred in this particular study, rather than the Heat Index (in Chapter 5) because it incorporated a radiant and convective component.

iii. Behavioural observations

I monitored the birds in partnership with participating farmers, on a daily basis for the duration of the study period. Parameters of interest included respiratory rates, shade-seeking behaviour and wing orientation.

a. Respiration rates

During the experiment, respiratory rates (breaths per min) of birds in each category were recorded during afternoons between 12:00 and 15:00. Respiratory rates for individual birds in each flock were counted as the number of breaths per minute. Due to difficulties in monitoring respiratory rates in free-ranging situations, breaths per minute were estimated by counting the number of breaths per 15 seconds and multiplying by four. Respiratory rates for all birds in each flock were counted every 15 minutes (Altmann, 1974) throughout ~3h observation periods. Observations from each household were averaged per village for growers, hens and cocks.

b. Shade-seeking and wing orientation

Instantaneous sampling method (Altmann, 1974) was used to record the behaviour of each individual bird in each flock to determine: a) whether birds sought shade or were in sunshine, and b) whether wings were elevated or not (that is orientation of wings). Scan samples (Altmann, 1974) of behaviour (that is shade-seeking and wing orientation) for all birds in each flock were made every 15 minutes, throughout ~3h observation periods each afternoon between 12:00 and 15:00. Observations of proportions (or %) of birds per village chicken category across all flocks and villages were averaged and plotted against the average WBGT Index.

iv. Body mass gain

During the study period, measurements of body mass were taken on a weekly basis for all chickens in each participating household using an automatic mini digital hanging scale (Brand: HTM; Capacity/Accuracy: 50kg/0.005kg; Model number: HT041, China). Body mass measurements were taken according to chicken category (that is growers, hens, cocks - as defined earlier). Body mass gain was calculated as the change in body mass between measurements.

6.3.4. Data Analyses

The WBGT Indices from each village were compared using analysis of variance (ANOVA) of SAS. Behavioural observations were also compared across village chicken categories using ANOVA Multiple-coefficient of determination between the WBGT Index and behavioural observations (that is respiratory rates, shade-seeking and wing orientation) for each village chicken category were used to establish the impact of high ambient temperatures on village chickens. Polynomial regression models were fitted to assess the relationships between WBGT Index and respiratory rates. Body mass gains for each category were correlated with WBGT Index to assess the influence of high ambient temperatures on village chicken production. All data were tested for significance at the 95% confidence level.

6.4 Results

6.4.1. Temperature, relative humidity and WBGT Index

The highest (~63.0ºC) daily maximum globe temperature measurement was recorded in January 2016, and the lowest (15.2ºC) in November 2015 (see Fig. 6.1). For air temperatures, the highest measurement (49.5ºC) was recorded in January 2016 and the lowest (21.9ºC) in November 2015 (see Fig. 6.2). Relative humidity measurements ranged from ~26% in March 2015 to ~97% in November 2015 (see Fig. 6.3). Although the lowest and highest values of the WBGT Index (see Fig. 6.4) were noted for Domboni in November 2015 (~17 ºC) and December 2015 (~44ºC), the WBGT Indices across villages were not statistically different (*P = 0.068*).

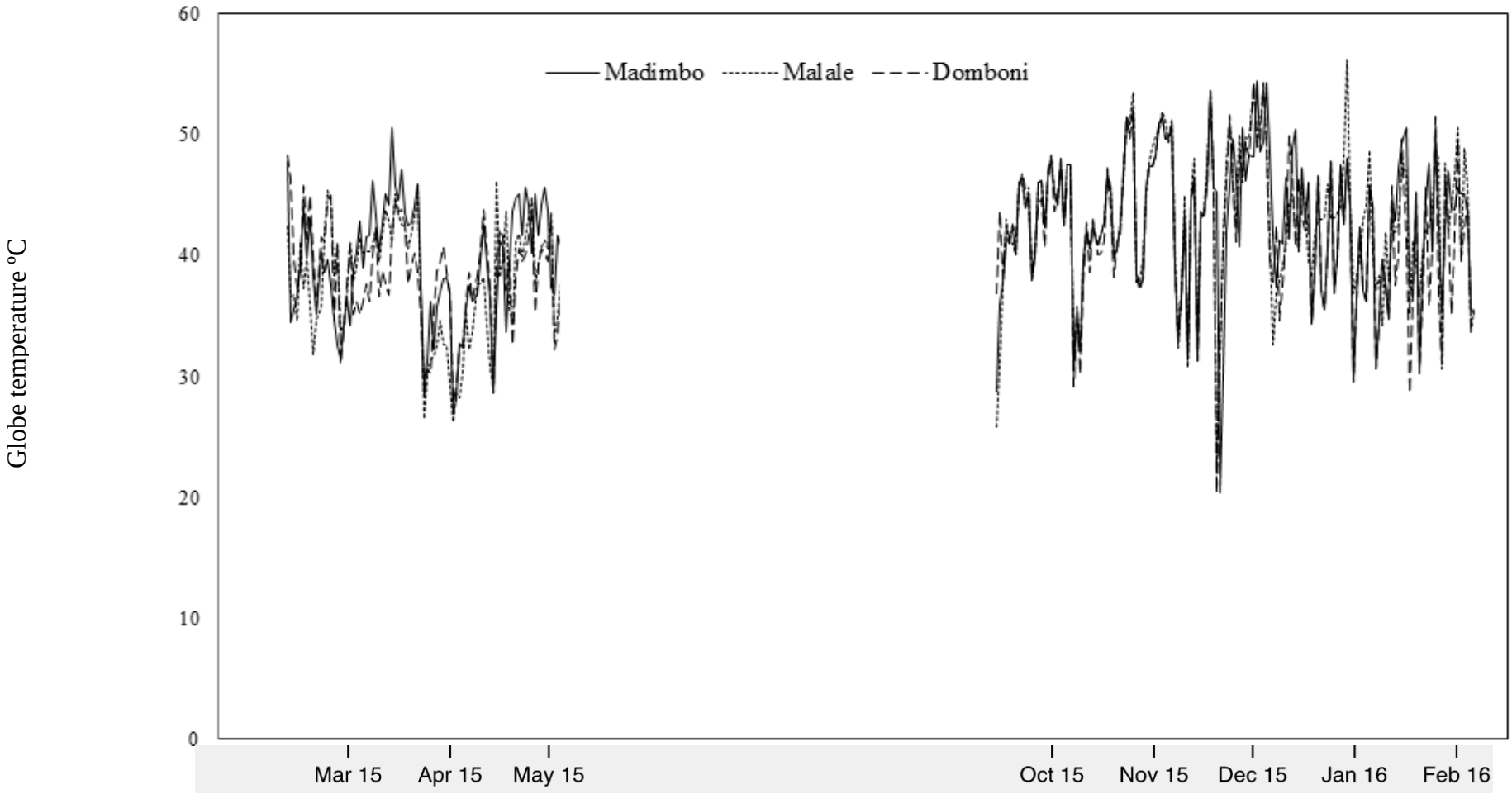


Figure 6.1: Comparison of daily maximum globe temperatures in the three villages of Musina (Madimbo, Malale and Domboni), for the period February 2015 - February 2016. Since the focus was on heat stress, no weather measurements were captured during the coldest months (June - August 2015).

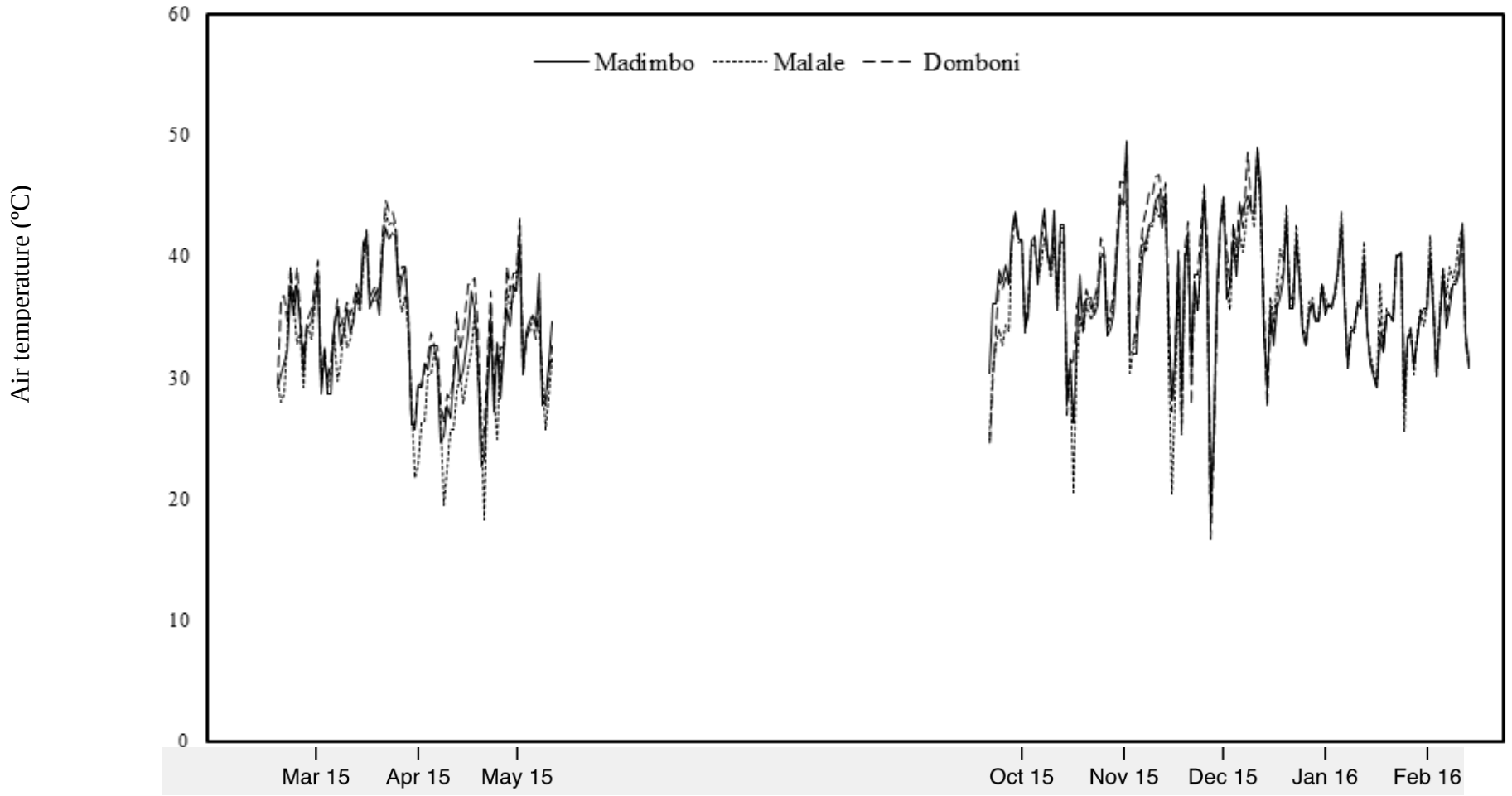


Figure 6.2: Comparison of daily maximum air temperatures in the three villages of Musina (Madimbo, Malale and Domboni), for the period February 2015 - February 2016. Since the focus was on heat stress, no weather measurements were captured during the coldest months (June - August 2015.

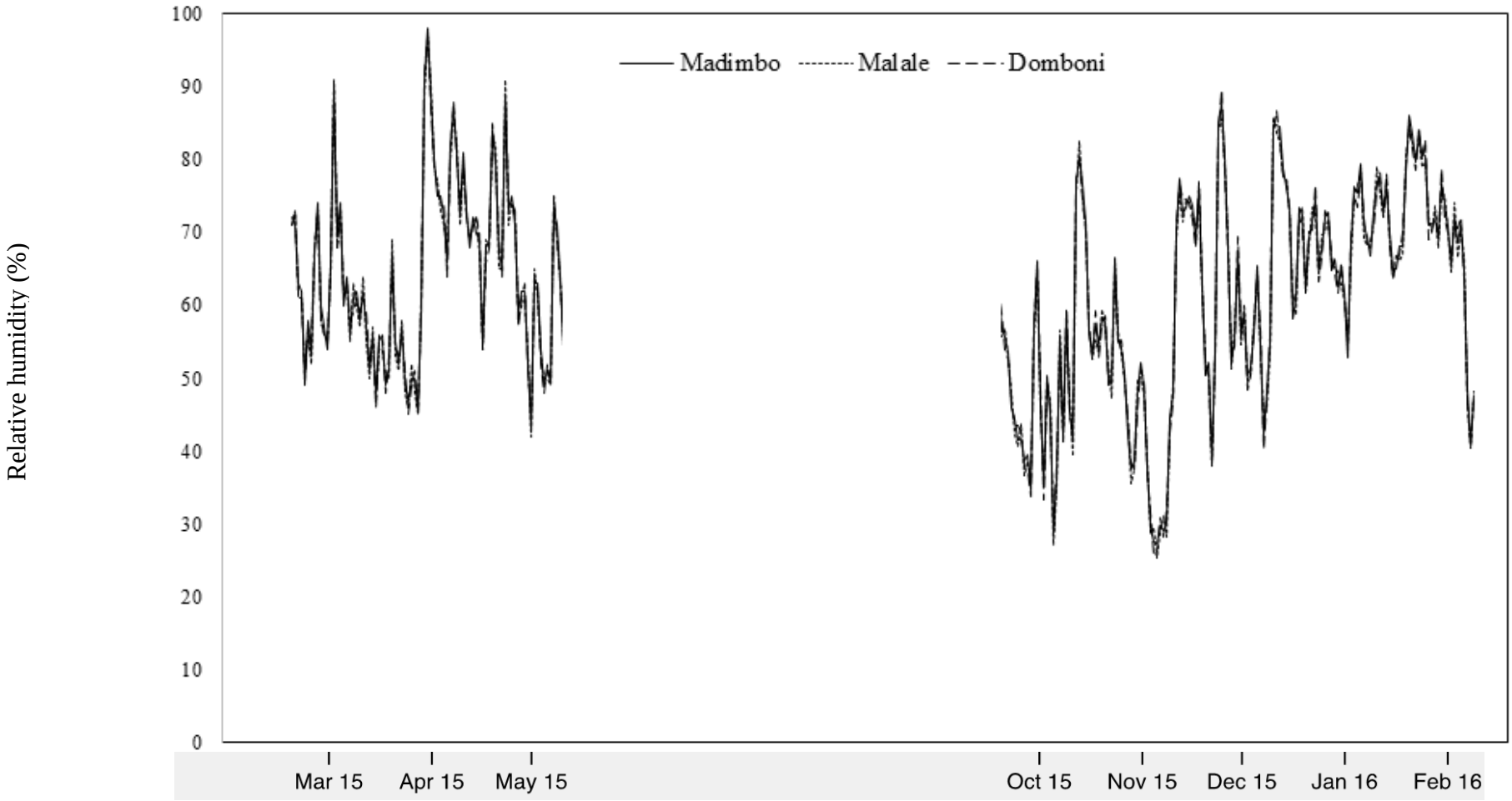


Figure 6.3: Comparison of daily average relative humidity in the three villages of Musina (Madimbo, Malale and Domboni), for the period February 2015 - February 2016. Since the focus was on heat stress, no weather measurements were captured during the coldest months (June - August 2015).

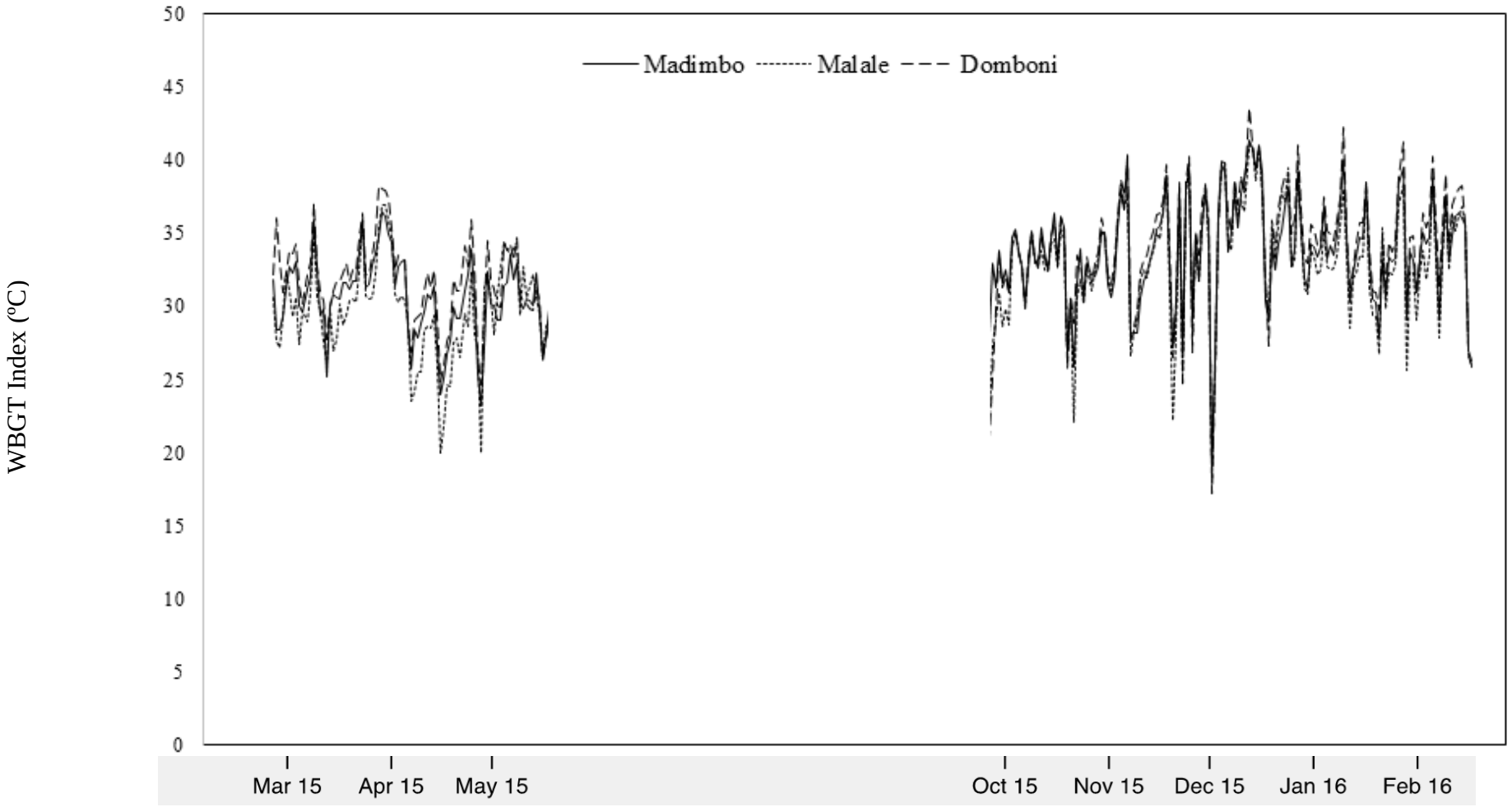


Figure 6.4: Comparison of daily Wet Bulb Globe Temperatures (WBGT) Index in the three villages of Musina (Madimbo, Malale and Domboni), for the period February 2015 - February 2016. Since the focus was on heat stress, no weather measurements were captured during the coldest months (June - August 2015).

6.4.2. Respiratory rates

The typical respiratory rates for growers, hens and cocks, correlated with WBGT Index, over the study period, are presented in Figure 6.5. The lowest and highest values of breaths per minute are noted for Domboni in November 2015 (that is ~32 breaths per min) for cocks and hens, and in December 2015 (that is ~220 breaths per min) for growers. Respiratory rates of the different chicken categories correlations positively with the WBGT Index in Malale ($R^2>0.6$), Madimbo ($R^2>0.8$) and Domboni ($R^2>0.7$). For instance, the WBGT Index accounted for ~87% of the variation observed in respiratory rates for growers in Malale, yet in Domboni, the WBGT Index only had a moderate (~67%) positive influence on the variation observed in respiratory rates for growers. One-way repeated-measures ANOVA indicated that there were significant differences ($P = 0.0274$) in respiratory rates between growers and hens ($F = 11.2$, $P = 0.0302$), as well as between growers and cocks ($F = 15.4$, $P = 0.0251$).

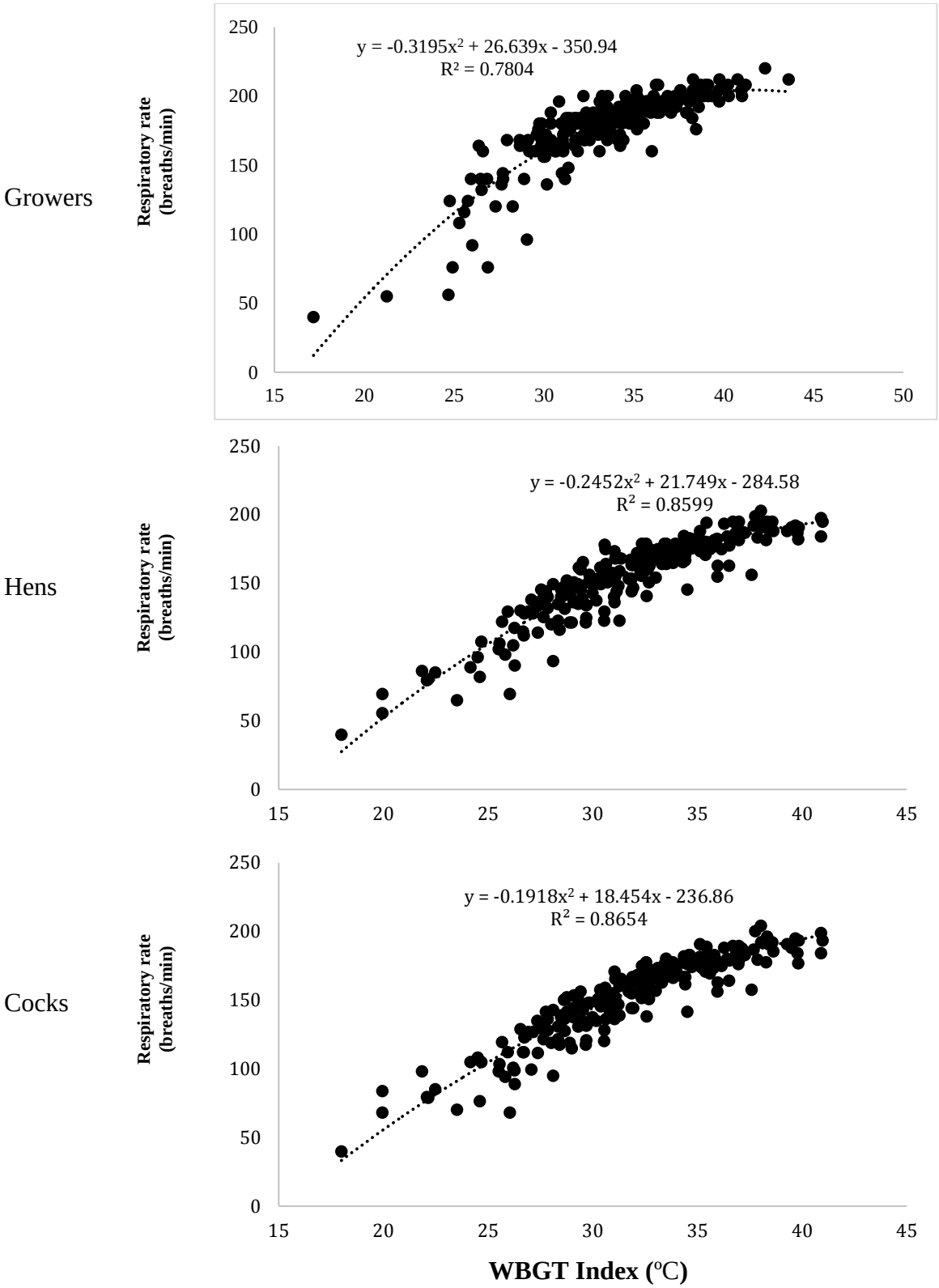


Figure 6.5: Average respiratory rates (breaths per min) of growers, hens and cocks for all flocks during the hottest time of the day (that is 12:00-15:00) correlated with WBGT (Wet Bulb Globe Temperature ºC) Index in the three villages of Musina (Madimbo, Malale and Domboni), for the period February 2015 - February 2016. Since the focus was on heat stress, no weather measurements were captured during the coldest months (June - August 2015). Each black dot represents average respiratory rate for all chickens within each category per day.

6.4.3. Shade-seeking behaviours

The village chicken shade-seeking behaviour was strongly positively correlated ($R^2>0.9$) with high WBGT Index. During the heat of the day, birds rested under shaded areas. For instance, at ~40ºC, almost all birds sought shade (see Fig. 6.6). However, some exceptional cases were observed, with some birds still under direct sunshine even at temperatures above 40ºC. However, such cases of exposure to direct sunshine at high ambient temperatures were not voluntary but rather forced through potential threats to birds (for example people, dogs etc.), and thus were not recorded as natural thermoregulatory behaviour. Observations of shade seeking behaviour across villages was not significantly different ($P = 0.274$).

6.4.4. Wing-orientation

Strong positive correlations ($R^2>0.9$) between wing orientation and WBGT Index were also observed during this study. Almost all birds spread their wings at ~45ºC (see Fig. 6.7). Generally, the lifting of wings seemed to start at ~32ºC, where approximately 30% of birds were observed to spread their wings occasionally. There were no significant category differences in wing orientation ($P = 0.54$), neither were there any significant differences in wing orientation across villages ($P = 0.215$).

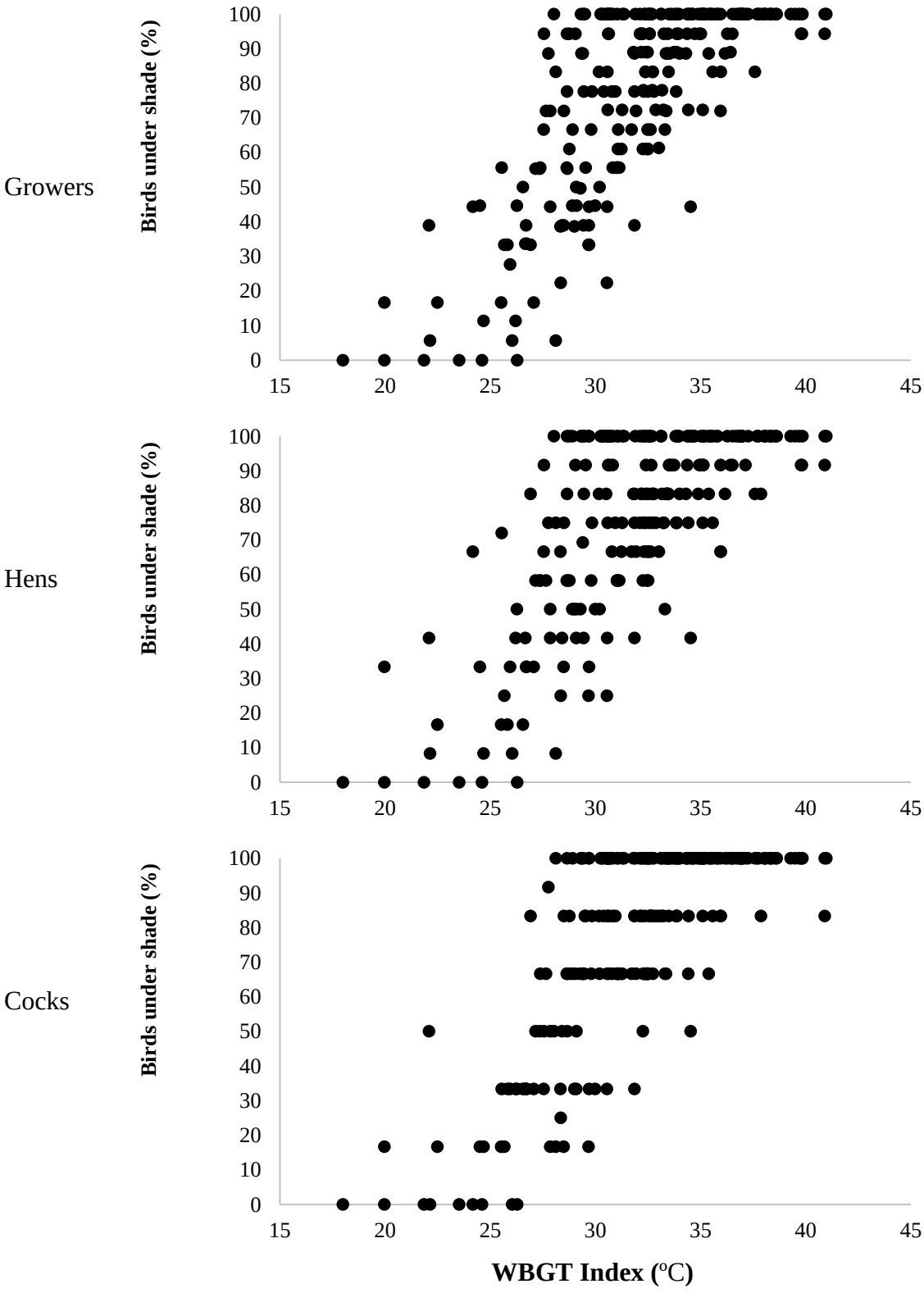


Figure 6.6: Average percentage (%) of growers, hens and cocks for all flocks under the shade during the hottest time of the day correlated with WBGT (Wet Bulb Globe Temperature ºC) in the three villages of Musina (Madimbo, Malale and Domboni) for the period February 2015 - February 2016. *Since the focus was on heat stress, no weather measurements were captured during the coldest months (June - August 2015).* Each black dot represents average percentage of birds under the shade for all chickens within each category per day

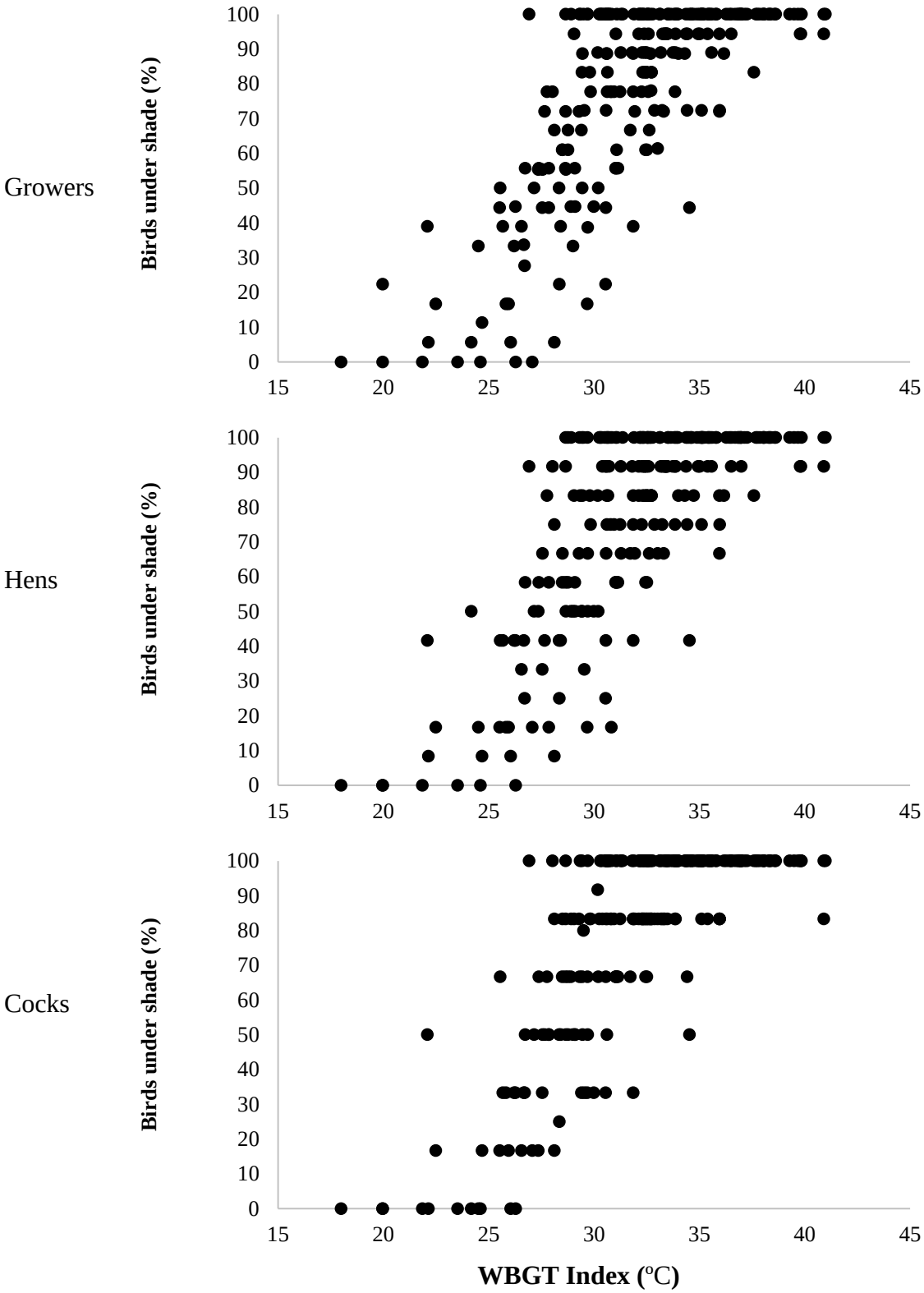


Figure 6.7: Average percentage (%) of growers, hens and cocks for 30 flocks with elevated wings during the hottest time of the day (that is 12:00-15:00) correlated with WBGT (Wet Bulb Globe Temperature ºC) in the three villages of Musina (Madimbo, Malale and Domboni) for the period February 2015 - February 2016. *Since the focus was on heat stress, no weather measurements were captured during the coldest months (June - August 2015).* Each black dot represents average percentage of birds under the shade for all chickens within each category per day.

6.4.5. Body mass gain

A high WBGT Index, although with a weak negative correlation (that is $R^2 = -0.24$), seemed to significantly ($P = 0.047$) retard body mass gain for growers. For instance, when the WBGT Index was lower than 32ºC, body mass gain of growers was ~39g per week. However, under warmer conditions (that is WBGT Index >32ºC) body mass gain was ~23g per week. For cocks, body mass gain seemed to decrease slightly above 32ºC from ~17g to ~12g per week. Hens had a body mass gain of ~28g per week below 32ºC, but this figure dropped to ~17g per week >32ºC.

6.5 Discussion

I have shown that village chickens increase their respiratory rates, seek shade and droop their wings when ambient temperatures increase. High WBGT Index also resulted in a decline in productivity as indexed by a reduction in body mass gain. This implies that prevailing high ambient temperatures in Musina are likely causing heat stress to village chickens and consequently affecting productivity. This finding is consistent with what has been reported in the literature, namely that hot weather conditions tend to cause heat stress in chickens, which in turn compromises the reproductive performance of the birds (Renaudeau et al., 2012; Abidin and Khatoon, 2013; Lara and Rostagno, 2013).

Village chickens exhibited some thermoregulatory responses (physiological indices) that are common under high ambient temperatures. For instance, respiratory rate, which normally ranges from 20 to 59 breaths per minute (Swick, 1998; Marchini et al., 2007), had a strong positive correlation with WBGT Index, and increased by almost four times the normal rate, at times. Although an increase in the rate of respiration serves as an efficient evaporative cooling thermoregulation mechanism by which birds lose excess body heat (Richards, 1970),

a high respiratory rate is also considered as evidence for a marked hypothermia (Silanikove, 2000; Pearce et al. 2013). Respiratory rates seem to be the most accessible and easiest method for evaluating the effect high ambient temperature has on farm animals (Silanikove, 2000).

Birds may also lose excess body heat to the environment through conduction, convection and radiation (Richards, 1970). Another thermoregulatory reflex response mechanism observed in this study was the spreading of wings when the WBGT index reached ~35ºC. However, spreading of wings allows birds to increase the surface area so as to lose excess body heat if air temperatures is less that the body temperature.

Generally, thermoregulation in younger birds is poorly developed (Aulie, 1976), causing them to be this more vulnerable to heat stress when compared to adult birds which have a well-developed and stable thermoregulation system. However, some studies have suggested that the stability of the thermoregulation system for hens is influenced by several factors that affect their ability to cope with prevailing weather conditions. For instance, changes in the physiology of hens when laying eggs and during incubation, makes them vulnerable, at times, to a number of stresses including heat stress (Tucker, 1943; Ericsson, 2016). In connection with incubation, hens develop specially modified areas of bare skin known as brood-patches, induced by the hormone prolactin secreted by the pituitary (Tucker, 1943; Angelier et al., 2015; Ericsson, 2016). Since feathers are poor conductors of heat, brood-patches are adaptations providing increased blood supply for the application of hen warmth to eggs under incubation (Tucker, 1943; Angelier et al., 2015). Thus, in hot weather, the incubation process, which generates heat, may be a further compounding factor to heat stress. In

addition, energy demands of laying birds and restricted feeding during incubation may compromise the ability of birds to respond to stress (Ericsson, 2016).

Free-ranging animals have the liberty to select preferred microclimates (Renaudeau et al., 2012; Kerr, 2015; Vizzotto et al., 2015). For instance, in the current study, when the WBGT Index was high (that is ≥ 40ºC), most birds voluntarily sought shade, moving to cooler local environments. Although the shade-seeking behaviour may significantly reduce radiant heat load of birds, it is likely that, in some instances, high ambient temperatures experienced in Musina offset the extent to which this thermoregulatory behaviour was useful. This is likely because the ambient temperature is the measure of how hot or cold the air is under shade. Further, because village chickens depend heavily on scavenging for their nutritional needs, actively seeking shade during the day may consequently result in inadequate feed intake. Interestingly, calculations of body mass gain (refer to Chapter 4, Section *4.4.2: Growth and development*) in the current study also had a negative correlation (although weak) with warming, implying that body mass gain is adversely impacted by an increase in the WBGT Index. Retarded body mass gain has a direct effect on both food security and the socio-economic status of the resource-limited farmers who mainly keep village chickens for consumption, and occasional generation of income.

The extent to which the productivity of village chickens is compromised by heat stress may be less though, compared to commercial chickens. Indigenous chicken species (including village chickens) represent a genetic resource that may be better adapted to local conditions than the commercial breeds (Besbes et al., 2007; Mtileni et al., 2012; Ngeno et al., 2014). As highlighted earlier, ambient temperatures above 30°C tend to cause heat stress in broiler production (Tankson et al., 2001). In my study, most birds (in all categories) seemed to employ thermoregulatory and evaporative cooling responses at ambient temperatures of

around 35ºC. This variation could be a function of several interrelated factors. For instance, one factor may be related to selection for fast growth in broilers, which makes birds highly sensitivity to heat stress (Soleimani and Zulkifli, 2010; Felver-Gant et al., 2012; Mack et al., 2013). It is also likely that village chickens may have adapted, to an extent, to high environmental temperatures due to prolonged or extended exposure to high ambient temperatures from a young age (Romanov et al., 1996; Charmantier et al., 2008; Ngeno et al., 2014). Some studies seem to suggest, however, that birds generally react in a similar manner to heat stress but may express individual variation in intensity and duration of responses (Hemsworth, 2003; Boissy et al., 2007; Soleimani et al., 2011; Lara and Rostagno, 2013). Studies under controlled environments would determine the source and extent of the variation between heat tolerance levels of village chickens and commercial poultry.

6.6 Conclusion

This study demonstrates that although hardy, village chickens in Musina are negatively affected by heat stress under contemporary hot weather conditions. As they scavenge for feed during the day, birds are sometimes exposed to excessively high ambient temperatures of ≥ 40°C, which forces to seek shades to reduce heat loads. In turn, this reduces scavenging, which probably translates to reduced feed intake and ultimately, poor body mass gain. It is thus likely that poor nutrition related to heat stress may be an important contributor to the overall poor productivity of village chickens. A reduction in body mass gain has implications for food security and the socio-economic status of resource-limited farmers. However, since village chickens are free-ranging, it is possible that other environmental factors, apart from heat stress, could have had an effect on overall body mass gain. It is critical that efforts to address village chicken production constraints must adopt a holistic strategy, as opposed to managing challenges in isolation. Research should also focus on the impacts of heat stress on

egg quality and quantity, as well as interactions between heat stress and other village chicken production challenges. Further, it will be imperative for future research to establish the source and extent of heat tolerance of village chickens, in comparison with the commercial breeds.

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CHAPTER 7

7.0 Concluding Discussion

7.1 Introduction

This chapter (i) discusses key findings on the impact of climate change (warming) on village chicken production, (ii) revisits the hypotheses, (iii) presents future work suggestions, and (iv) outlines implications of this study.

7.2 Climate change and village chicken production

Despite village chickens contributing meaningfully to rural households in Musina, it is unfortunate that most flock exits were in the form of losses (for example predation and theft), rather than for family consumption and income generation. Such losses could be reduced by improvements in feeding, and confinement of younger birds to chicken housing structures. Provision of secure shelter at night could also protect adult birds from theft. Interventions such as feeding, and housing will, however, require financial resources and technical capacity, which is usually lacking in resource-limited rural households.

Village chicken flock sizes and structures varied across seasons (see Table 5.1 & 5.2). For example, flock sizes were highest in spring (~23), summer (~20), autumn (~18) and winter (~16). Further, highest body masses were recorded over the spring and summer seasons (see Fig. 5.1 & 5.2). Notably, village chickens seem to be more productive (for example number of eggs produced per hen per clutch) during the warmer seasons, compared to colder ones. Such variation in productivity can be attributed to multiple factors, such as changes in daylight length over the warmer seasons, which promotes egg production, as one example. In

addition, there is usually an abundance of feed resources in the local environment for birds to consume as they scavenge during warmer seasons (Wingfield et al., 2000).

Another key seasonal variation observed in village chicken production was the prevalence of health challenges. There were more incidences of parasitic infestations in summer compared to winter. Consequently, farmers engaged in health care initiatives against infestations more over the warmer periods of the year compared to colder periods. Generally, farmers relied on traditional or indigenous remedies to address perceived health changes, which is common in most rural communities of developing countries (Tanyanyiwa and Chikwanha, 2011). However, remedy effectiveness in addressing health challenges was neither clear nor ascertained. Lack of supporting evidence on the extent of the effectiveness of traditional remedies is an important challenge when it comes to indigenous knowledge systems (Mapfumo et al., 2013). Further, traditional remedies may prove ineffective against emerging pathogens, likely to become prevalent with changing vector distributions, under climate change.

Besides common challenges with regard to health, knowledge, productivity, amongst others, in village chicken production, the general upward warming trend in the global mean surface temperatures is expected to further aggravate existing challenges and is likely to present new ones (Nyoni et al., 2018). Findings in the current study also show that temperatures have generally increased, and that weather conditions (that is temperature and relative humidity) have become more variable. Such changes in climatic conditions are expected to adversely affect village chickens through heat stress (Bhadauria et al., 2014).

Certain earlier studies have associated selection for rapid growth with increased susceptibility of poultry (particularly broilers) to heat stress (Cahaner et al., 1995; Berong and Washburn, 1998; Nienaber and Hahn, 2007). Rapid growth generates more heat, which may eventually cause bird mortality. Since rural poultry is characterized by slow growth rates, it is possible that they are less susceptible to the impact of heat stress, when compared to commercial breeds. In this study, farmers also perceived that their village chickens are hardy enough to cope with projected temperature increases. These perceptions are also consistent with what certain studies have suggested - namely that indigenous chicken species represent a genetic resource that may be better adapted to the local environments, compared to commercial chickens (Besbes et al., 2007; Mtileni et al., 2012; Ngeno et al., 2014). Further, other reports indicate that village chickens possess hereditary traits that are pertinent to their adaptation to local environmental conditions (Romanov et al., 1996; Ngeno et al., 2014). It is thus likely that both genetic variation and previous exposure influence the extent to which village chickens can be affected by heat stress. However, it remains questionable whether village chickens can sustain their productivity under high ambient temperatures.

This study showed that high ambient temperatures may be causing heat stress to village chickens. A weak negative correlation ($R^2 = -0.24$) between the WBGT Index and body mass gain was one of the key indicators that birds were adversely impacted by high heat loads. In addition, village chickens exhibited certain thermoregulatory behaviours (physiological indices), such as high respiratory rates, elevated wings and shade-seeking behaviour, that are common in hot environments. Although an increase in respiratory rate is necessary for evaporative cooling (Richards, 1970), high respiratory rates also indicate that birds are experiencing heat stress (Pearce et al. 2013). Further, effective evaporative cooling requires adequate (or regular) access to water, which was not the case in the current study. Spreading

of wings to increase the surface area to lose excess body heat (that is convective cooling) is only effective if there is a gradient for heat loss from the bird to the environment. Further, seeking shade is an important mechanism that birds used to reduce radiant heat loads . Shade-seeking behaviour presents a trade-off with foraging, however. Since village chickens basically scavenge for feed during the day, shade-seeking may have reduced time spent foraging and ultimately resulted in a reduction in body mass gain at high ambient temperatures. The role of agricultural extension agents in providing empirical evidence to farmers is important for improving village chicken productivity in rural areas.

7.3 Summary of findings (Conclusion)

This study sought to investigate the impact of climate warming (temperature) on village chicken production in Limpopo province, South Africa. Based on the findings of this study, one hypothesis (that is ***Null Hypothesis 2***) is accepted and the other three are rejected (refer to section 1.7 Null Hypotheses). Farmers did not perceive climate changes as a challenge in village chicken production. However, empirical evidence suggests that village chickens may be adversely impacted by a warming climatic system (heat stress). Below is a list of rejected Null Hypotheses (*that is Null Hypotheses 1, 3 and 4*).

Null Hypotheses 1: Seasonal, annual and decadal temperature and relative humidity trends have not changed in Musina;

- *Mean temperatures have increased*
- *Temperatures and relative humidity have become more variable*

Null Hypotheses 3: There is no seasonal variation in village chicken flock dynamics and management practices;

- *There were seasonal variations in flock dynamics and some management*

Null Hypotheses 4: Village chickens are not affected by heat stress.

- *Observed physiological indices and body mass gain revealed that village chickens are negatively impacted heat stress*

7.4 Future studies

Overall, village chickens have the potential to contribute meaningfully to food and nutrition security in rural areas of developing countries. It would be prudent for local governments and developmental partners to pay increased attention to this agricultural sub-sector to improve the livelihoods of rural people. Although observed thermoregulatory behaviours are instrumental indicators of the impact of heat stress on village chickens, there is a clear need for future research to further assess the effects of heat stress on village chickens. Measurement of body temperature would be essential to quantify heat stress. Birds could be implanted with temperature monitoring data loggers (for example i-Buttons) to assess body temperature changes during experiments.

Conducting experiments under controlled environments in the laboratory would also be important in complimenting field studies. For instance, although village chickens panted excessively (~200 breaths per minute) in some cases during hot periods of the day, lab-studies would ascertain whether panting was sufficient to prevent an increase in body temperature. Further, village chicken heat load thresholds could be more easily determined in the lab. For instance, holding all other production factors (for example feeding and health issues) constant and altering only temperature and relative humidity (heat stress factors) could help establish the impact of high heat loads on village chickens productivity (for example egg quality). This could further help with comparisons between breeds and establishment of the extent of heat tolerance.

Egg quality is also an important indicator of heat stress. It would be relatively easy to assess egg parameters such as point of lay, frequency in laying of eggs, size of eggs, mean number of eggs laid, weight of eggs, shell colour, texture, cleanness and soundness more accurately in the lab compared to the field.

Other key next steps in research would be to use the future mechanistic climate change predictions to model when village chickens are likely to exceed thresholds of adaptation. These data may need to be collected first by researchers in partnership with local communities. Provision of scales to measure body mass gain could also help the farmers to monitor body mass gain, and probably appreciate the value of supplementary feed.

In addition, it would be important for this research on the effects of high ambient temperatures on village chicken to be scaled up across the country so as to establish best management strategies across an aridity and temperature gradient. If village chickens prove unsustainable in the future, it might be necessary for farmers and researchers to consider other poultry species (for example guineafowl). Further, future research on small scale farming should also focus on a bigger understanding of the importance of local livestock breeds, and how climate change is affecting their productivity.

7.5 Implications, perspectives and significance

Rural poultry constitute a large and significant portion of the livestock sector in the rural areas. It is likely that village chickens and other poultry species (for example turkeys, geese, ducks etc.) in rural areas of developing countries (for example Africa) are negatively affected by high heat loads. High heat loads may compromise growth and development and reduce productivity (for example body mass gain and egg production). Adverse impacts of climate

change ultimately translate to reduction of benefits (for example family consumption and generation of petty cash in emergencies) derived from this sub-sector, as well as reduced realization of it is potential. Because small-holder farmers typically depend directly on agriculture for their livelihoods and have limited resources and capacity to cope with shocks, any reductions to agricultural productivity can have significant impacts on their food security, nutrition, income and well-being (Hertel and Rosch, 2010; McDowell and Hess, 2012).

It will be imperative for farmers to intentionally improve their village chicken management practices, specifically in terms of: housing at night to reduce theft; housing and supplementary feeding chicks to reduce predation; supplementary feeding the flock particularly in winter when natural available resources may be limited; candling eggs to identify infertile eggs and increase household protein consumption; providing water for birds in summer to avoid dehydration while panting to stay cool. However, such efforts to improve village chicken production will require financial and technical support from local governments and developmental agencies.

There is a clear need for climate and sustainable agriculture research in the region to continue establishing the impact of climate changes and variability on specific on small-scale agricultural farming systems and consider relevant adaptation options. Several climate change related issues still need to be understood with regards to village chicken production, which include the effect of heat stress on egg quality and quantity, as well as intricate interactions between high ambient temperatures and other village chicken production challenges. There is need, also, for appropriately trained and informed agricultural extension agents to help farmers understand climate change related challenges and opportunities for

improving rural poultry farming. Further, it would be essential for researchers to interact with farmers to find sustainable solutions in addressing the impacts of climate change.

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APPENDICES

A. Household Questionnaire

CLIMATE CHANGE AND RURAL POULTRY PRODUCTION HOUSEHOLD QUESTIONNAIRE

COMPLETE BEFORE THE INTERVIEW

Respondent name:	**Surname:** _____ **First name:**_____ **Gender: 1= Male 2= Female** |___|	**Questionnaire numbering:**
Date :	|__|__| / |__|__| / **2014** *Day Month*	
Interviewer Name:	_____	|___|___|___|___|___| |_ questionnaire #|
ID	|___|___|___|	
Supervisor Name	_____	First two digits to represent village code _____ **=01** _____ **=02** _____ **=03** _____ **=04**
ID	|___|___|___|	
Location ID :	**District Municipality:** |_____| **Local Municipality:** |_____| **Village:** |_____| **GPS Coordinates***:* |_____|	Last three digits to represent questionnaire number (#) for example questionnaire number 1 would be 001, number 10 would be 010 and number 100 would be 100

Greeting/Explanation: This questionnaire is in support of a research to "Establish the Impacts of Climate Warming on rural poultry farming in Limpopo Province - Musina Local Municipality, South Africa". This initiative aims to investigate the impact of climate warming (temperature) on rural poultry performance. Thereafter, the researchers intend generating innovative methods, technologies and approaches through research so as to enable rural poultry farmers to better manage climate-related risks on poultry production. The results from this research will be shared with the government and its development partners to support planning, implementation and monitoring of farmer climate warming risk adaptation activities.

SECTION 1 – DEMOGRAPHICS

A household (HH) is defined as a group of people who eat daily or at least frequently from the same pot and live in the same compound (or physical location) for at least 3 months. It is possible that they may live in different structures

1.1	**What** is the sex **of the household head**? Male = 1; 2=Female	|___|

1.2	What year was the household head born?	|__|__||__|__|	
1.3	What is the marital status of the head of household? 1= Married/single spouse 2= Married/Polygamous 3=Widowed 4=Separated/divorced 5=Cohabiting 6=single/never married 7=Other (specify)	|___|	
1.4	**Can** the household head **read and write**? *(in any language)* Yes = 1 ; No=0	|___|	
1.5	**Is** the head of household functionally **disabled**? Yes = 1; No=0	|___|	
1.6	What is the highest **level of education of the household head**? 0=None 1= Primary 2= Secondary; 3= Tertiary; 4= vocational 5= other	|___|	
1.7	What is the **employment status of the household head**? 1= formally employed; 2=Not employed ;3=self-employed 4=fulltime farmer; 5=part-time farmer; 6=Casual/temporal worker; 7=farm labourer 8=student 9=other (specify)	|___|	
1.8	What is the household head's farming status? 1=Full-time farmer; 2=Part-time farmer	|___|	
1.9	How many children and adults are currently living in the HH?	Male |___|	Female |___|
	Total	|____|	
1.10	Please give breakdown of the household by the following age ranges	Male	Female
	0-5 years	|___|	|___|
	6-11 years	|___|	|___|
	12-17 years	|___|	|___|
	18-59 years	|___|	|___|
	Above 60 years	|___|	|___|
1.11	Are there any members who are or were chronically ill in the last 12 months? (Diabetes, BP, TB, HIV etc.) (Give number)	|___|	
1.12	How many members **are fit to work in agriculture** related operations (crop/livestock management)?	Male |___|	Female |___|
1.13	How many **members stay off farm?** (away but rely on this HH for example school children in boarding schools)	Male |___|	Female |___|

SECTION 2 – HOUSEHOLD COPING STRATEGIES		
2.1 Were there any days in the past 12 months that your household faced difficulties in accessing enough food to eat? 1=Yes; 0=No (If No skip to Section 5) |___|		
2.2 If Yes, how frequently did your **household** resort to using one or more of the following strategies in order to deal with the food access difficulties during that period?		
Coping Strategies		**Frequency** **Never =1** **Seldom=2** **Sometimes** (1-3 days per month)**=3** **Often** (1-2 days per week)=**4** **Daily** (3-6 days a week)**=5**
2.2.1	Skip entire days without eating?	|___|

2.2.2	Limit portion size at mealtimes?	|___|
2.2.3	Reduce number of meals eaten per day?	|___|
2.2.4	Borrow food or rely on help from friends or relatives?	|___|
2.2.5	Rely on less expensive or less preferred foods?	|___|
2.2.6	Purchase/borrow food on credit?	|___|
2.2.7	Gather unusual types or amounts of wild food / hunt?	|___|
2.2.8	Harvest immature crops?	|___|
2.2.9	Produce food through off-season cropping	|___|
2.2.10	Divert seed to food consumption	|___|
2.2.11	Rely on community 'food-for-work' programmes?	|___|
2.2.12	Rely on rations from local leadership/NGOs?	|___|
2.2.13	Reduce adult consumption so children can eat?	|___|
2.2.14	Rely on casual labour for food?	|___|
2.2.15	Has your household sold/bartered any household assets to buy food in the past 3 months? 1 = Yes; 0 = No |___| *NB. As a way of coping with difficulties in accessing adequate food*	

SECTION 3 –LIVESTOCK PRODUCTION

A: Inventory

Livestock Type	**Total Number Owned** **If None, put zero**	**What is the main source of water for each type of livestock?** 1=Dam 2=River 3=Tap water 4=Borehole 5=Vleis/springs 6=well 7=other	**Do you have adequate water for all livestock categories that you keep in all seasons?** 1=Yes 0=No	**What is the main environmental challenge greatly affecting livestock production in your area?** 1=Rainfall 2=Temperature 3=Grazing/ feeding 4=Pests & diseases 5 =lack of water 6=Don't know	**Explain the main socioeconomic challenge you face for each livestock enterprise.** 1= lack of feed 2= lack of shelter 3=poor extension service 4= lack of markets 5=theft 6=No labour for husbandry 7=Lack of knowledge 8=other
3.1.1 Cattle	|___|	|___|	|___|	|___|	|___|
3.1.2 Sheep	|___|	|___|	|___|	|___|	|___|
3.1.3 Goats	|___|	|___|	|___|	|___|	|___|
3.1.4 Chickens	|___|	|___|	|___|	|___|	|___|
3.1.5 Turkeys	|___|	|___|	|___|	|___|	|___|
3.1.6 Donkeys	|___|	|___|	|___|	|___|	|___|
3.1.7 Pig	|___|	|___|	|___|	|___|	|___|
3.1.8 Guinea fowl	|___|	|___|	|___|	|___|	|___|
3.1.9 Ducks	|___|	|___|	|___|	|___|	|___|
3.1.10 Geese	|___|	|___|	|___|	|___|	|___|
3.1.11 Pigeons	|___|	|___|	|___|	|___|	|___|
3.1.12 Rabbits	|___|	|___|	|___|	|___|	|___|
3.1.13 Fisheries	|___|	|___|	|___|	|___|	|___|
3.1.14 Other (specify)_____	|___|	|___|	|___|	|___|	|___|

3.2	**Please indicate how your herd/flock sizes have changed in the last 30 years and the reasons for the changes.**						
	Livestock	**Average herd/flock sizes**		**Reason for change recent 2 yrs****		**Reason for change 10-30 yrs****	
		Recent 2 years	10-30 years ago,	Change	Reason	Change	Reason
3.2.1	Cattle	|___|	|___|	|___|	|___|	|___|	|___|
3.2.2	Sheep	|___|	|___|	|___|	|___|	|___|	|___|
3.2.3	Goats	|___|	|___|	|___|	|___|	|___|	|___|
3.2.4	Turkeys	|___|	|___|	|___|	|___|	|___|	|___|
3.2.5	Donkeys	|___|	|___|	|___|	|___|	|___|	|___|
3.2.6	Pig	|___|	|___|	|___|	|___|	|___|	|___|
3.2.7	Chickens	|___|	|___|	|___|	|___|	|___|	|___|
3.2.8	Guinea fowl	|___|	|___|	|___|	|___|	|___|	|___|
3.2.9	Ducks	|___|	|___|	|___|	|___|	|___|	|___|
3.2.10	Geese	|___|	|___|	|___|	|___|	|___|	|___|
3.2.11	pigeons	|___|	|___|	|___|	|___|	|___|	|___|
	Other(specify)	|___|	|___|	|___|	|___|	|___|	|___|

Change; 1=increase; 2=Decrease0=No Change

** reasons for decrease
1=Disease related death 2=Drought related death
3=Sold/slaughtered 4=Theft 5=Paid lobola 6=predation
7= weather related (heat wave, excessive rains)
8=Others

**reasons for increase
1=Purchased (buying in)
2=Natural increase (calving)
3=Donations/gifts
4=Received from lobola
5=good management 6=less livestock diseases
7=others

Please fill in the following Tables

3.3	**Livestock**	Rank according to importance 1=most important 2=fairly important 3=least important 4=Not important	Please give a reason
3.3.1	Cattle	|___|	
3.3.2	Sheep	|___|	
3.3.3	Goats	|___|	
3.3.4	Poultry	|___|	
3.3.5	Donkeys	|___|	
3.3.6	Other? Specify_____ ___	|___|	

3.4 Poultry		Village chickens	Ducks	Turkeys	Guinea Fowls	Pigeons	Other (Specify)
3.4.1	Price (R)						
3.4.2	Eggs laid per annum (on average)						
3.4.3	Chicks hatched per batch						
3.4.4	Chicks survival to maturity						

3.5 What is your criterion for rankings the above livestock species? 1=Finances 2= Draft power 3=Food 4=Prestige 5=Ease of management 6=Other (Specify) _____ |___|

3.6 If you bring in chickens (as presents, bought etc) how do you introduce them in the flock?

_____

_____

3.7 Give a reason for the number of chicks hatched per batch?

_____

3.8 State the reason(s) for the number of chicks that survived to maturity

_____

_____

3.9 Is chicken production an economical practice to you? 1=Yes 0=No |___|

3.10 State the reasons for the above-mentioned answer_____

3.11 What is your selection criterion for the chickens you farm with? 1=Size 2=Type/(Breed) 3=Colour 4=Finances 5=Other? Specify _____ |___|

B: Nutrition

3.12 Do you feed your poultry? 1=Yes 0=No |___|

3.13 Do you give specific feed to your poultry at different stages of growth (chick, grower and mature)? 1=Yes 0=No |___|

3.14 What method do you use for feeding your poultry? 1=Feeding troughs 2=Throw to the ground 3=Other? Specify _____ |___|

3.15 What type of supplementary feed do you give to your poultry? 1=None 2=Maize grain 3=Wheat 4=Sorghum 5=Millet 6=Kitchen wastes 7=Sunflower 8=Other (Specify)

_____

3.16 Frequency of feeding? 1=Once a day 2=Twice a day 3=Thrice a day 4=Anytime 5=Other (Specify) _____ |___|

3.17 For how long do your poultry scavenge for feed per day? 1=Whole day; 2=Morning only; 3=Afternoon only |___|

3.18 Give a reason for the answers(s) above? 1=convenience; 2=security; 3=availability of feed 4=Other (Specify)_____ |___|

3.19 How does the season affect nutrition of your chicken? 1=increases; 2=decreases; 3=No effect **Cold** |___|

Hot |___|

3.20 Do you provide water for your poultry (chickens)? 1=Yes 0=No |___|

3.21 How has nutrition changed over time?

_____

_____

_____

C: Housing

3.22 Do you provide housing for your village chickens? 1=Yes 0=No |___|

3.23 If no, where do your chickens stay overnight? 1= Open space, 2=Trees 3=Other? Specify _____ |___|

3.24 If yes, please fill in the following table:

Housing structure	
Roofed	
Solid wall	
Solid wall + Fence	
Soil/Earth Floor	
Cement Floor	

3.25 Why did you decide to build such a structure? 1=Security 2= Convenience 3= Cost 4=Other? Specify _____ |___|

3.26 Do you clean the chicken houses? 1=Yes 0=No |___|

3.27 Do you collect chicken faecal matter for use as manure for your gardens and/or field? 1=Yes 0=No |___|

3.28 Is there another way you would have liked to build the fowl run? 1=Yes 0=No |___|

3.29 If so, why? _____

3.30 How would you like it to be built?

_____

_____

3.31 What are the implications of your type of housing on productivity of chickens? 1=Increases 2=Decreases 3=No effect 4=Other/ Specify _____ |___|

3.32 How has housing changed over time?

_____

_____

_____

D: Health

3.33 Do you experience any health problems in rural poultry production? 1=Yes 0=No |___|

3.34 If Yes, what are the various health problems? 1=Diseases 2=Parasites 3=Both diseases and parasites 4= Malnutrition 5=Wounds 6=Other? Specify _____ |___|

3.35 Please fill in the table below

	Fatality 1=Yes 0=No	1=most prevalent 2=moderate 3=least prevalent 4=Not prevalent
Diseases	|___|	|___|
Internal parasites	|___|	|___|
External parasites	|___|	|___|

Di: Parasites

3.36 How do you tell that the chickens are infested with the said parasites? 1=Dullness 2=Scratching 3=Reduced Feed Intake 4=Fluffed Feathers 5= inspection 6=Other (Specify)

_____

6.33.1 Internal parasites _____ |___|

6.33.2. External parasites _____ |___|

3.37 Give a description of the answers given above:

6.34.1 Internal parasites

_____

6.34.2 External parasites

_____

3.38 What are the impacts of the parasites on chickens? 1=Reduced growth 2= Reduced egg production 3= Both 4=Death 5=Other Specify _____ |___|

3.39 What are the seasonal differences in the occurrence of the parasites?

6.36.1Internal parasites _____

6.36.2 External parasites _____

3.40 From your knowledge, do they affect a few HH, whole village, or various villages? 1=Few HH 2=Whole village 3=Various 4=Villages

6.37.1 Internal parasites |___|

6.37.2 External parasite |___|

3.41 Do these parasites also affect humans? 0=No 1=Yes

6.38.1Internal parasites |___|

6.38.2 External parasites |___|

Dii: Poultry Diseases

3.42 Give a description of the signs for the diseases that are prevalent

_____

_____

_____

3.43 Rank these diseases according to morbidity (if knowledgeable)

Disease	Rank according to which are the most common 1=most common 2=moderate 3=least common 4=Not prevalent
New Castle	|___|
Avian Cocidiosis	|___|
Diarrhoea	|___|
Fowl cholera	|___|
Fowl coryza	|___|
Fowl pox	|___|
Marek's disease	|___|
Other (Specify)	|___|

3.44 What are the seasonal differences in the occurrence of the disease?

6.42.1Cold Season _____

6.42.2 Hot Season _____

3.45 Do they affect a few HH, whole village, or various villages? 1=Few HH 2=Whole village 3=Various Villages

3.46 How do you tell that your poultry are infested with the said parasites? 1=Dullness 2=Scratching 3=Reduced Feed Intake 4=Fluffed Feathers 5=Other (Specify)

_____ |___|

3.47 Do these diseases effect on you and/or anyone in your HH? 0=No 1=Yes |___|

3.48 If Yes, how? _____

3.49 How has poultry health changed over time?

_____

_____

_____

E: Health management

3.50 For the mentioned problematic parasites and diseases, do you normally control them?

6.46.1 Internal parasites 0=No 1=Yes |___|

6.46.2 External parasites 0=No 1=Yes |___|

6.46.3 Disease 0=No 1=Yes |___|

3.51 If yes, how do you control parasites and diseases? 1=Conventional Drugs; 2=Traditional Practices; 3=Both; 4=None; 5=Other (specify) _____

6.47.1 Internal parasites |___|

6.47.2 External parasites|___|

6.47.3 Disease |___|

3.52 Why do you use Ethno-veterinary practices to control parasites and treat diseases? 1=Cheap 2= Locally Available 3=Highly Effective 4= Other? Specify_____ |___|

3.53 If ethno-veterinary practices are not used, why? 1=Religion 2=Culture 3=Not Interested 4=Not knowledgeable 5=Other? Specify _____ |___|

3.54 Which conventional drug(s) do you use to control the most prevalent parasites and diseases?

6.50.1 Internal parasites _____

6.50.2 External parasites _____

6.50.3 Disease _____

3.55 Do you use conventional drugs? 0=No 1=Yes, |___|

3.56 If Yes, please fill in the table below.

Conventional drug (s)	Source	Quantities used	Parasite/ diseases controlled	Mode of application	Frequency of application	Cost	Age of chickens treated

3.57 Where do you keep the drugs after using them?

1=Local stores; 2=Department of Agriculture; 3=NGOs; 4=Other Specify _____ |___|

3.58 If using alternative remedies, please fill in the table below.

Alternative remedies	Type of parasite controlled	Application method	Frequency of application	Precautions taken when using the remedies	How long have you been using this remedy?

3.59 Which of the above is most effective? _____

3.60 Why do you say so? _____

3.61 Fill in the following table if medicinal plants are used.

Plant name	Source	Preparation method	Parasite/ diseases controlled	Mode of application	Frequency of application	Age of chickens treated	Precautions when using these remedies

3.62 For how long have you been using these practices in your chicken flock? 1=<2 yrs; 2=2-5yrs; 3=6-10 yrs; 4= 11-20 yrs; 5= >20 yrs |___|

3.63 How has health management changed over time?

_____

_____

_____

SECTION 4 – FARMER PERCEPTIONS ON CLIMATIC AND ENVIRONMENTAL CHANGES

4.1 Have you noticed any changes in the following environmental factors over the last 10-30 (1983-2013) years? Please explain.

	Factor	Noticed change 1=Yes 0=No 2=don't know	If Yes, how?	Change
4.1.1	Mean temperature	|___|	1= Increased 2=Decreased 3=range altered 4= Other	|___|
4.1.2	Mean rainfall	|___|	1= Increased 2=Decreased 3=range altered 4=Other	|___|
4.1.3	Frost/snow occurrences	|___|	1 = Increased 2=Decreased 3= No change 4=Other	|___|
4.1.4	Uncontrolled veld fire occurrences	|___|	1 = Increased 2=Decreased 3=Other	|___|
4.1.5	Vegetation cover	|___|	1= Increased bush encroachment 2=Decreased bush encroachment 3=Reduced herbaceous cover 4=Increased herbaceous cover 5= Other	|___|
4.1.6	Wetlands area	|___|	1= Emergence of wetlands 2= Disappearance of wetlands 3=Other	|___|

4.2 Have you noticed any changes in poultry production in the last 10-30 years? Please explain

	Factor	Noticed change 1=Yes 0=No 2=Don't know	Kind of change 1=Increased 2= Decreased 3=Changed seasonality 4= Other (specify) _____	Have you noticed any climate related patterns associated with the change?
4.2.1	Point of lay (maturity)	|____|	|____|	
4.2.2	Number of Eggs produced	|____|	|____|	
4.2.3	Clutches per annum	|____|	|____|	
4.2.4	Chicks hatched (%)	|____|	|____|	
4.2.5	Chick survival (%)	|____|	|____|	
4.2.6	Size of birds	|____|	|____|	

4.3 Have you noticed any change in the following poultry parasite and disease related factors in the last 10-30 years? Please explain

	Factor	**Noticed change** 1=Yes 0=No 2=Don't know	**Kind of change** 1=Increased 2= Decreased 3=Changed seasonality 4=New species 5=Other	Have you noticed any climate related patterns associated with the change?
4.3.1	Animal **parasite**/vector abundance	|____|	|____|	
4.3.2	Animal **parasite**/vector seasonality	|____|	|____|	
4.3.3	Animal **disease** prevalence, severity	|____|	|____|	
4.3.4	Animal **disease s**easonality	|____|	|____|	
4.3.5	Did you make any adjustment to these changes? 1=Yes 0=No			Explain adjustment
4.3.6	Animal parasite/vector abundance and seasonality	|____|		
4.3.7	Animal disease prevalence, severity and seasonality	|____|		

4.4	**Please indicate the specific parasites and diseases that have increased in abundance and prevalence, and severity, respectively. (you can use local names)**		
		That have **increased** in prevalence	That have **decreased** in prevalence
4.4.1	Livestock parasites	1|_____| 2 |_____| 3|_____| 4|_____|	1|_____| 2 |_____| 3|_____| 4|_____|
4.4.3	Livestock diseases	1|_____| 2 |_____| 3|_____| 4|_____|	1|_____| 2 |_____| 3|_____| 4|_____|

4.5	**What adjustments in your poultry farming have you made to these changes?**	**Explain**
4.5.1	Temperature	
4.5.2	Rainfall	
4.5.3	Frost/snow occurrences	
4.5.4	uncontrolled veld fire	
4.5.5	Parasite prevalence and seasonality	
4.6.6	Disease prevalence, severity and seasonality	
4.6	Have you noticed any other changes in your poultry production over the last 10-30 years? 1= Yes; 0=No	|___|
4.7	Explain what has changed and why you think it has changed?	

SECTION 5 – PERCEIVED LIVESTOCK FARM-LEVEL ADAPTATION STRATEGIES

5.1	REF responses to **7.5**: Why did you not use any of the following adaptations?	**Did you use adaptation strategy?** 1= Yes 0=No	**Main reasons for not using adaptation.** 1= lack of money, 2= lack of information/knowledge 3= shortage of labour 4= Not relevant/necessary 5=Others
5.1.1	Changed from crops to livestock	|___|	|___|
5.1.2	Changed from livestock to crops	|___|	|___|
5.1.3	Adjust livestock management practices	|___|	|___|

5.1.4	Changing use of chemicals, fertilizers, manure and pesticides	|___|	|___|
5.1.5	Do off-farm income generation activities	|___|	|___|
5.1.6	Prayer/Cultural adaptations	|___|	|___|
5.1.7	Other adaptations	|___|	|___|

SECTION 6 ACCESS TO INFORMATION AND USE OF INDIGENOUS KNOWLEDGE SYSTEM

6.0 Do you have access to information on rural poultry production? 1=Yes; 0=No |___|

6.1	**Please indicate your access to the following information, the sources and adequacy of the information for decision making**						
	Type of information	Do you access information 1=Yes 0=No	**Three** mains sources of information 1=Gvt extension 2=radio/television 3=newspapers 4=other farmers 5=relatives/children 6=other gvt dept. 7=NGOs;8= Education Institution 9= Indigenous10=other	Rate timeliness of the information 1=good 2=fair 3=poor	Rate reliability/adequacy of information for decision making 1= good 2=fair 3=poor	Do you use Indigenous knowledge for the indicated types of information? **Usage** 0=No, 1=traditional leaders 2= Community leaders 3= elders 4= on observation & experience 5=Others	**Reliability** 1= good 2=fair 3=poor
6.1.1	Production and health related information	|___|	|___||___||___|	|___|	|___|	|___|	|___|
6.1.2	Livestock Markets and prices	|___|	|___||___||___|	|___|	|___|	|___|	|___|
6.1.3	Climatic/weather in general	|___|	|___||___||___|	|___|	|___|	|___|	|___|
6.1.4	Seasonal forecasts	|___|	|___||___||___|	|___|	|___|	|___|	|___|

B. Publications and conferences

PUBLICATIONS

Nyoni, N. M. B., Archer, E. and Grab, S. (2018). Heat stress and chickens: climate risk effects on rural poultry farming in low income countries. *Climate and Development Journal (In Press).*

Nyoni, N. M. B., Robyn, H., Archer, E. and Grab, S. (2018). Perspectives on the impact of climate change on rural poultry production in South Africa: a case study of Limpopo Province. *Submitted to the International Journal of Agricultural Sustainability for publication.*

Nyoni, N. M. B., Robyn, H., Archer, E. and Grab, S. (2018). Seasonal flock dynamics and management: characterizing village chicken production in South Africa. *Submitted to the journal of Tropical Animal Health and Production for publication.*

Nyoni, N. M. B., Robyn, H., Archer, E. and Grab, S. (2018). Temperature and relative humidity trends in Musina, South Africa: 1950–2016. *Submitted to the South African Journal of Science for publication.*

Nyoni, N. M. B., Archer, E., Grab, S. and Robyn, H. (2018). How How hot is too hot for hardy chickens? Impact of heat stress on village chickens in northern South Africa. *Submitted to the Poultry Science Journal for publication.*

CONFERENCES

Nyoni, N. M. B. (2018). Global Challenges, Local Solutions and Connected Pathways. 3rd International Conference on Global Food Security, Cape Town International Convention Centre, Cape Town, South Africa, 03 – 06th December 2017. Elsevier in association with the DST-NRF Centre of Excellence in Food Security and the Universities of the Western Cape and Pretoria. *(Conference and Side-Event participant)*

Nyoni, N. M. B. (2018). Catalysing local innovations and action to accelerate scaling up of CSA. The 4th Global Science Conference on Climate Smart Agriculture, Birchwood Hotel, Johannesburg, South Africa, 28 – 30th November, 2017. New Partnership for Africa's Development (NEPAD) Agency. *(Conference and Side-Event participant)*

Nyoni, N. M. B., Archer, E. and Grab, S. (2016). Impact of climate warming on village chicken production in Southern Africa. Africa Climate Change Adaptation initiative (ACCAI) Conference, 2 – 4 November 2016, University of Dar es Salaam, Tanzania. *(Oral and Poster)*

Nyoni, N. M. B., Archer, E. and Grab, S. (2014). Climate warming and rural poultry production in Southern Africa. 6th Wits Cross-Faculty Graduate Symposium, University of the Witwatersrand, South Africa, 28 - 29th October 2014. *(Poster)*

Nyoni, N. M. B., Archer, E. and Grab, S. (2014). Climate warming and rural poultry production in Southern Africa. International Conference on African Agriculture, Rural Development and Sino-Africa Cooperation (CAARDSAC 2014) and 16th Jiangsu International Agri-expo, Nanjing, China, 21-28th September 2014. *(Oral)*

Nyoni, N. M. B. (2014). Positioning policies, institutional frameworks & research in Africa. Third AfriCAN Climate Award and Climate Smart Agriculture Conference at Leriba Lodge in Centurion, Pretoria, 22 – 24th April 2014. Food Agriculture and Natural Resources Policy Analysis Network (FANRPAN).