Exploring water quality and farmers' perceptions about water and food security in the Vaalharts Irrigation Scheme

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“We have become,
by the power of a glorious evolutionary accident called intelligence,
the stewards of life's continuity on earth. We did not ask for this role,
but we cannot abjure it.
We may not be suited to it, but here we are.”

Stephen Jay Gould, *The Flamingo's Smile: Reflections in Natural History*

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List of Abbreviations

DAFF: Department of Agriculture Forestry and Fisheries

DWAF: Department of Water Affairs and Forestry

EC: Electrical conductivity

FAO: Food and Agricultural Organisation

ICP-MS: Inductively coupled plasma mass spectrophotometry

NPSNS: National Policy for Food and Nutrition Security

NDP: National Development Plan

PSPPDII: Program to Support Pro-poor Policy Development

TDS: total dissolved solids

TWQR: Target Water Quality Range

WRC: Water Research Commission

WHO: World Health Organization

WWF: World Wide Fund for Nature

Summary

Food insecurity has been linked to increased risks of non-communicable diseases such as diabetes and heart disease and, in the case of South Africa, disparities in terms of access to diverse diets, affect household food security status. The government of South Africa devised the National Development Plan (NDP) 2030 with an aim to address food insecurity by promoting rural development which includes an increase in irrigated agriculture. The plan is supported by the National Policy for Food and Nutrition Security (NPFNS) which acknowledges the four dimensions of food security, namely; availability, access, utilisation and stability. Additionally, there is increasing interest in nutrition sensitive agriculture which, among other goals, aims to combine nutrition education with agriculture and prioritise sustainability and resilience within conservation concerns.

Farm practices and interactions with natural resources may affect sustainable food security, particularly in a country where the agricultural sector struggles with a lack of availability of arable land and unreliable rainfall. Furthermore there is a need to consider the quality of natural resources. Water quality, for example, may impact crop health, yield, crop diversity and the stability of food production. This water should be managed, regularly monitored and maintained. It is within this context, that the National Water Act of 1998 serves as an important document emphasising water value as a common asset and holds all water users accountable for its protection, including farmers.

This study explored the relationship between water quality and food security by integrating a quantitative analysis of water from the Vaalharts Irrigation Scheme with a qualitative exploration of perceptions of local farmers on water quality and food security.

The water quality was deemed fit for irrigation use, with caution that prolonged irrigation use requires monitoring due to salinity and pH. Nitrates, phosphates and metals were within ideal ranges. Overall, farmers perceived the water quality negatively, but their perceptions were in line with salinity results. The integrated results indicated that farmers' perceptions of water quality influenced the mitigation techniques they selected, without knowing the exact levels of constituents they were mitigating against. Farmers displayed practical knowledge in terms of salinity, and felt that knowing more about the quality of the water would benefit food production. Farmers considered negative influences of water quality to be external to the farm boundary. Likewise, maintenance and management were perceived to be the responsibility of the service provider and at national and local government levels. Overall, the farmers' perceptions showed that water quality was linked to food production and food security.

The study recommends that there be reciprocal knowledge transfer between all actors involved in water and agricultural services. When available, water quality results of the Vaalharts Irrigation Scheme as well as recommended mitigation techniques should be shared with the farming community. The concept of "water stewardship" prompted by the World Wide Fund for Nature (WWF) could raise awareness and involve farmers in taking ownership of water quality. Where applicable, updated versions of the national water quality guidelines should consider including aspects of sustainable agriculture as a part of the mitigation techniques as well as reiterate the pivotal role of the farmer as a responsible actor. The NDP 2030 and other policies promoting

agricultural development should be aware of the quality of natural resources and not just concentrate on availability.

Keywords

Water quality, Vaalharts Irrigation Scheme, food security, perceptions, agriculture

Section 1: Introduction

1.1 Background

Despite being food secure at national level (United Nations System Standing Committee on Nutrition 2013), South Africans at household level experience disparities in accessing diverse diets which can lead to malnutrition (Labadarios et al. 2011; Pereira et al. 2014; Schönfeldt et al. 2010). Pereira et al. (2014) further indicate that food security is tied to increased risks of non-communicable diseases such as heart disease and diabetes. The South African government has recognised the link between poverty and the unequal access to high-quality and diverse diets. The efforts of the National Development Plan (NDP) are aimed at reducing poverty and inequality by 2030, of which a significant component is directed toward ensuring national food security through the expansion of irrigated agriculture and promotion of labour intensive crops (National Planning Commission 2012). The NDP 2030 recognizes that the manner in which agricultural initiatives are carried out is important and is thus supported by the National Policy on Food and Nutrition Security (NPFNS) (DSD and DAFF 2013). The NPFNS takes all four dimensions of food security into consideration; namely availability, access, utilisation and stability and can be complimented by nutrition sensitive agriculture, through an emphasis on nutrition education, strengthening governance and stability and resilience of the farm environment (McLachlan and Landman 2013). The focus of the NPFNS and nutrition sensitive agriculture have arisen due to the possible impacts that farm practices can have on access, utilisation and stability of food security (Godfray et al. 2010).

Farming in South Africa is characteristically difficult due to limited arable land and variable rainfall (DAFF 2015; Goldblatt 2010) and one method of maximising production potential has been the development of irrigation schemes (Tilman et al. 2002). The Vaalharts Irrigation Scheme is the largest and one of the oldest schemes in South Africa (Van Vuuren 2010). Situated in the Northern Cape Province the scheme links the Vaal and Harts Rivers through approximately 300 km of canals. The original design was essentially a rural development project aimed at supporting poor white farmers in the 1930's (Van Vuuren 2009). Despite the current high level of agricultural production the local community is considered poor with low employment rates (Claasen 2015). A large variety of crops are still produced in the region, including staple grains that are reliant on the Vaalharts Irrigation Scheme which distributes irrigation water according to a set quota system (Verwey and Vermeulen 2011). The scheme falls within the Vaal catchment area and is impacted by upstream activities along the Vaal River that include mining, industry and various other urban effluents (WRC 2016). These influences could potentially affect the quality of the water in the scheme and subsequently food production itself.

Water quality is defined as the "*physical, chemical, biological and aesthetic properties of water that determine its fitness for a variety of uses and for the protection of aquatic ecosystems*" (DWAF 1996). The state of water quality can be influenced by the presence of constituents which are components dissolved or suspended in water column (DWAF 1996). In terms of agriculture, salinity, the levels of sodium or calcium that affect ion toxicity (sodium, chloride and boron), and excessive nutrients (eg. nitrogen) are of concern (Ayers and Westcot 1994). Levels of certain constituents in the water can affect crop health, yield and crop choice (Van Rensburg et al. 2011;Qadir et al. 2008; Chapman 1998). Salinity, in particular, is often a concern for crop production due to the inhibiting effect on the soil water osmotic potential (Van Rensburg et al. 2011). The pH is included as an indication of water quality as it influences chemical processes within the water itself (Chapman 1998). The pH also interferes with the micronutrient uptake, may impact plant health and marketability and can be corrosive on irrigation implements (DWAF 1996). Increased nutrients (for example phosphates and nitrates) may be toxic to aquatic life forms in the ecosystem (De Villiers and Thiart 2007) and outflows high in nutrients may lead to eutrophication of the river system (Codd 2000), further impacting the national reserves. Fluctuations in salinity and constituents such as pH, nutrients and metals, indicate changes in the quality of water and fitness for use, with different requirements for drinking, agriculture, industry and recreation (Chapman 1998). Farming practices may have an effect on the quality of the water (Armour and Viljoen 2000). These studies highlight the need for water quality to be monitored and maintained through policing of water users and applying necessary processes and practices where possible.

Historically, water use legislation in South Africa stated that a land user situated at a water source had the right to use of the water (Perret 2002). More recently, the National Water Act of 1998 emphasises that water is a common asset and holds water users accountable for any contribution to water pollution (Republic of South Africa 1998). A practical application of the National Water Act 1998 can be illustrated in the concept of "water stewardship" as advocated by the World Wide Fund for Nature (WWF). Water stewardship supports active participation of farmers in water quality management through awareness and action plans at farm level and beyond the fence (WWF 2014).

Water use is regarded as a form of farm practice and Nguyen et al. (2016) show that a farmers' willingness to adapt farm practices, such as improving irrigation practices can be linked to their perceptions regarding their adaptive capabilities. "Perceptions" is a broad concept but in the context of this study, can be viewed in terms of risk perceptions, whereby experience may drive the "risk, benefit" judgement and lead to behaviours, such as pesticide use (Slovic et al. 2005). Blackstock et al. (2009) draw the link between understanding behaviour in order to tackle behaviour change amongst farmers to improve water quality, emphasising the need to understand the psycho-social context of a particular farming community. Additionally, Bartholomew et al. (2011) refer to the concept of capability which refers to knowledge and skills necessary for successful interventions and behaviour change.

South African studies that explore farmers' perceptions of water quality highlight that their perceptions were influenced by knowledge and understanding of water quality processes (Saldías et al. 2016) and municipal management (Liefferink 2015). Influences on farmers' willingness to adapt farm practices included elements such as knowledge and awareness (Gandure et al. 2013) as well as their capacity to adapt, which in-turn was influenced by their social-economic status (Wilk et al. 2013). Literature in South Africa that focusses on farmers perceptions of water quality, against the backdrop of food security is minimal.

1.2 Problem statement

As a key resource in food production, there is a need to explore the relationship between water quality and food production within the sphere of food security. Assessing the degree of alignment between farmer's perceptions and actual water quality indicators would highlight gaps and opportunities within the food production system of the Vaalharts Irrigation Scheme.

1.3 Aims and objectives

The aim of the study was to explore the relationship between water quality, farmers' perceptions of water quality and food security in the Vaalharts region.

The specific objectives were:

1. To assess the water quality of the Vaalharts Irrigation Scheme and its potential impact on local food production by small, medium and large scale farmers in the Vaalharts region (the various farm sizes were selected as to be representative of the region).
2. To determine the present water quality of the Vaalharts Irrigation Scheme and return flows in terms of priority pollutants and system variables such as turbidity, pH, salts, and micronutrients.
3. To explore perceptions of water quality among small, medium and large scale farmers of the Vaalharts region and its impact on food production and food security.
4. To integrate and compare the actual state of the water quality of the Vaalharts Irrigation Scheme with farmer's perceptions of water quality.

1.4 Research design

The research design applied in this study is a convergent parallel design within a mixed methods approach (Cresswell 2014). Data collection and analysis of irrigation water from the Vaalharts Irrigation Scheme occurred concurrently with a qualitative inquiry and analysis of farmers' perceptions of water quality and its impact on food production and food security over the period of approximately a year (March 2016 to January 2017). Data were integrated by examining specific constituents and their recommended mitigation techniques in comparison with the farmers' perceptions and their mitigation choices.

1.5 Ethical approval and considerations

Precautions to minimize risks to participants of the qualitative data collection included an informed and signed consent form and the use of participant codes to ensure confidentiality. Training on qualitative interview techniques and quantitative sampling was received prior to engaging in field work. Participants were informed they could withdraw at any time. It was made clear that there would not be monetary benefits for the participants or the researchers, and that their participation was voluntary.

The participants were informed of the time that the interviews would take and permission to record was obtained prior to the interview.

Ethical approval to conduct the study was attained from the Health Research Ethical Committee (HREC) of the North-West University, ethics approval number: NWU-00351-15-A1.

1.6 A note on transdisciplinary health promotion

This masters requires an understanding from the student about the aspects of transdisciplinarity and health promotion. The scope of the article format did not allow for elaboration on the theoretical aspects of transdisciplinarity and health promotion. However, the undertaking of this study showed that a transdisciplinary approach should be considered in future endeavours to promote rural development that supports local food security to help create solutions to the complex problems related to food security and nutrition related health concerns in South Africa. The aspects of transdisciplinarity reflected in this study are derived from its application of a mixed methods approach, the combination of both social and physical sciences from inception, and the multidimensional understandings of reality across multiple role players in the scheme (Nicolescu et al. 1994). The study further highlights the scope for health promotion by recognising the value of *advocating* for the awareness of water quality and health related food security concerns (WHO 2016).

Although not the focus in the article itself, the conclusion of this dissertation will be within the framework of transdisciplinary health promotion as the recommendations reflect ideals such as *enabling* a sense of control among actors, appreciating that exchanges of knowledge need to be *mediated* and the implied contribution to national *policies* (WHO 2016).

1.7 Outline of this dissertation

The dissertation is written in article format and contains three sections:

Section 1: Introduction

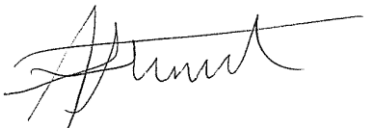
Section 2: The article: “Exploring water quality and farmers' perceptions about water and food security in Vaalharts” as prepared for the journal *Agriculture and Human Values*

Section 3: Conclusion, limitations and recommendations

1.8 Authors share

The following table (Table 1.1) depicts the contributions made by the author and co-authors, as well as permission from the co-authors to submit the article to the journal of Agriculture and Human Values.

Table 1.1: Authors contributions and permission to submit

Position	Name	Contributions to study	Signatures
First author	Mrs Aimee Leigh Claassens	– Field work – Laboratory analysis – Data and interpretation, – Compiling of article.	
Co-author	Dr Nicole Claasen	– PI of larger project – Research design – Training and supervision of qualitative data collection – Supervision of research activities – Reviewing and support with structure and content of compiled dissertation.	
Co-author	Dr Wynand Malherbe	– Research design – Training and supervision of quantitative data collection – Supervision of research activities – Reviewing and support with structure and content of compiled dissertation.	

1.9 Selected journal

The journal selected for article submission is *Agriculture and Human Values,* published by Springer. It is the official journal of the Agriculture, Food, and Human Values Society and the scope includes understanding the underlying relationships that impact the agri-food system such as policies, governance and practices and their impacts on the environment.

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Section 2 Article for submission to the journal of Agriculture and Human Values

*Article requirements in Appendix. Headings and numbering will be presented as if in the article and is not collated with the dissertation table of contents.

Title page as to be included for submission to the journal of Agriculture and Human Values

Author: Aimee Leigh Claassens

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Exploring water quality and farmers' perceptions about water and food security in Vaalharts, South Africa

Abstract

More than half of South African households are food insecure. The National Development Plan (NDP) 2030 aims to address food insecurity by promoting rural development through initiatives such as increased irrigated agriculture. Although the plan is supported by the National Policy for Food and Nutrition Security (NPFNS), there is a need to consider interactions with natural resources. This study explored the relationship between water quality and food security by integrating an analysis of water quality from the Vaalharts Irrigation Scheme with perceptions of local farmers on water quality and food security. Water quality was deemed fit for irrigation use but with caution that prolonged irrigation use needs to be monitored. Overall, farmers perceived the water quality negatively and their perceptions were in line with salinity results. The integrated results indicated that farmers' perceptions of water quality influenced the mitigation techniques they selected. Farmers felt that the influence of and responsibility for water quality was external to the farm boundary. Perceptions showed that water quality was linked to food production and food security. The study recommends knowledge transfer between stakeholders whereby mitigation techniques are included in the monitoring and disseminating of Vaalharts Irrigation Scheme water quality results. The concept of water stewardship could raise awareness and involve farmers in taking ownership of water quality. The suggested mitigation techniques in the national guidelines should be updated with sensitivity towards sustainable agriculture and emphasise the role of the farmer as a pivotal actor in maintaining water quality, on and beyond the farm gate.

Keywords

Water quality, Vaalharts Irrigation Scheme, food security, perceptions, agriculture

Introduction

The Food and Agricultural Organization (FAO) states that food security exists when "all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life" (FAO 2003). This definition encompasses the multi-faceted nature of food security, including its four dimensions of availability, access, utilisation and stability (Charlton 2016). Availability focusses on the supply of food from a production perspective, the amount of stock at hand and implications of trade on food availability. Access, in turn, looks at how the supply reaches the plate in terms of buying behaviour, income, economics and markets. Utilisation considers the nutritional status of individuals and households in a community, including nutrient uptake, food safety and dietary diversity (FAO 2008). The stability dimension looks at the "at all times" aspect of the other dimensions (Charlton 2016). Godfray et al. (2010) acknowledge that farm practices have an

impact on the stability dimension of food security, and consider “sustainable intensification” in an endeavour to feed more people with the same or less available resources. Sustainable or conservation agriculture is gaining interest in South Africa, with initiatives such as looking at farm practices that are adapted to promote soil health (Kutu 2012), ecological sustainability (Rockstrom et al., 2004) and water conservation (Gandure et al. 2013). These studies show that beyond access to natural resources, the sustainability and quality of these resources should be taken note of.

At a national level South Africa is characterised as food secure (United Nations System Standing Committee on Nutrition 2013), but this is not the case at household level, with 28% being at risk of hunger and 26% experiencing hunger (Shisana et al. 2013). The National Development Plan (NDP) aims to reduce inequality and poverty in South Africa by 2030 and views agriculture as a priority sector in this endeavour due to its potential to improve livelihoods as a whole, including food security (NPC 2012). The NDP 2030 aims to uplift rural communities through revenue and labour opportunities by expanding irrigated agriculture and labour intensive crops such as citrus and vegetables (NPC 2012). The agricultural activities suggested by the NDP 2030 are supported by the National Policy on Food and Nutrition Security (NPFNS) which is sensitive towards the four dimensions of food security (DSD and DAFF 2013). Similarly, in practical application, there is an increased focus on nutrition sensitive agricultural approaches that aim to address livelihood inequalities by linking nutrition education to agricultural initiatives, strengthening governance, reducing inaccessibility to diverse diets and prioritising sustainability and resilience within conservation concerns in South Africa (McLachlan and Landman 2013).

Water quality is defined as the “physical, chemical, biological and aesthetic properties of water that determine its fitness for a variety of uses and for the protection of aquatic ecosystems” (DWAF 1996). Physical and chemical parameters of the water can affect crop health, yield and crop choice (Van Rensburg et al. 2011; Qadir et al. 2008; Chapman 1998). Salinity, in particular, is often a concern for crop production due to its inhibiting effect on the soil water osmotic potential (Van Rensburg et al. 2011). Fluctuations in salinity and of additional constituents such as pH, nutrients and metals indicate changes in the quality of water and fitness for use, with different requirements for drinking, agriculture, industry and recreation (Chapman 1998).

In South Africa, water use legislation prior to democracy in 1994 was rooted on a riparian principle whereby a land user situated at a water source had the right to use water (Perret 2002). More recently, the National Water Act of 1998 emphasises that water is a common asset and holds water users accountable through a mandate of mitigation for any contribution to water pollution (Republic of South Africa 1998). A practical application of the act has been “water stewardship” as advocated by the World Wide Fund for Nature (WWF) which supports the active participation of farmers in water quality management through awareness and action plans at farm level and beyond the fence (WWF 2014). Studies exploring farmers’ perceptions of water quality in South Africa showed that their perceptions were influenced by trust in the treatment process (Saldías et al. 2016) and management of water at a municipal level (Liefferink 2015). Farmers’ willingness to adapt farm practices was influenced by their knowledge and awareness (Gandure et al. 2013) as well as their socio-economic status, capacity to adapt and governmental support of the agricultural sector (Wilk et al. 2013).

Agricultural activities contribute 14% to the South African Gross Domestic Product (GDP), use over 80% of land and an estimated 60% of available water (Goldblatt 2010). The sector is confronted by difficulties in that only 13% of South Africa's agricultural land is considered arable due to climate, variable rainfall and soil viability (DAFF 2015; Goldblatt 2010). Due to the low average rainfall of less than 500 mm per annum, climatic and geographic variability and high levels of evaporation, it is estimated that only 8.5% of that rainfall translates into useable runoff (Benhin 2006). Farm practices such as the genetic modification of seeds, pesticides and fertiliser use, as well as the development of irrigation schemes all aim to maximise the production potential under these challenging conditions (Tilman et al. 2002). The Vaalharts Irrigation Scheme in the Northern Cape Province of South Africa is an example of maximising resources in an arid region that contributes to food production in the country (Van Vuuren 2010). This paper describes the relationship between water quality and food security by integrating quantitative analysis of water quality from the Vaalharts Irrigation Scheme with local farmers' perceptions of water quality and food security.

Methodology

The research applied a convergent parallel design within a mixed methods approach (Cresswell 2014). Data collection comprised of a quantitative assessment of irrigation water quality and a qualitative inquiry of farmers' perceptions of water quality and its impact on food production and food security in the research area. Data were then integrated in the results section.

1. Research area

The Vaalharts Irrigation Scheme encompasses almost 300 km of canals that link the Vaal and Harts Rivers and includes the communities of Jan Kempdorp, Hartswater, Vryburg, Magagong, Spitskop, Springboknek, Taung, Pampierstad, Pudimoe, Ganspan and the edge of Delportshoop (Vaalharts Water n.d., accessed June 2016). Crops produced in the region and reliant on irrigation are a combination of perennial crops like citrus, grapes, olives and pecan nuts as well as seasonal crops such as maize, wheat, cotton, oats, potatoes and lucerne (Verwey and Vermeulen 2011). The scheme falls within the Vaal River catchment and water quality is influenced by upstream activities along the Vaal River which include mining, industrial, agricultural and urban activities (WRC 2016).

2. Quantitative assessment of irrigation water

Water samples were taken bi-monthly from public irrigation canals (n=14) across the scheme (see Fig 1) to provide a snapshot of the present irrigation water quality. Samples were taken from the Vaalharts Weir (N=6), inflow canals (N=42) and outflow canals (i.e. agricultural return flows) (N=36) between March 2016 and January 2017. All samples were frozen until laboratory analysis. Analysis focussed on total dissolved solids (TDS), electrical conductivity (EC), pH, sodium (Na), phosphates (PO_4^{3-}), nitrates (NO^{3-}), ammonium (NH_4^{+}), nitrites (NO^{2-}) and sulphates (SO^{4}). Additionally phosphorous (P), potassium (K), zinc (Zn), chloride (Cl) and calcium (Ca)) and selected metals were also analysed. *In situ* analysis of TDS, EC, and pH was conducted during

sampling using an Extech DO610 water quality meter (Extech Instruments, A FLIR Company, USA).

A Merck Pharo 100 Spectroquant (Merck KGaA, Germany) and associated test kits were used in the laboratory (methods adapted from Vlok et al. 2013) to determine PO_4^{3-}, NO^{3-}, NH_4^+ and SO^4. A defined volume (50 ml) of each sample was filtered through pre-weighed 0.45µm cellulose nitrate filter paper using a vacuum pump (methods adapted from Malherbe et al. 2015). The following selected parameters were analysed with an Agilent 7500CE Inductively Coupled Plasma – Mass Spectrophotometer (ICP-MS): sodium (Na), phosphorous (P), potassium (K), zinc (Zn), chlorine (Cl), calcium (Ca), aluminium (Al), magnesium (Mg), vanadium (V), chromium (CR, manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), selenium (Se), arsenic (As), molybdenum (Mo), cadmium, (Cd) uranium (U), and lead (Pb).

Historical water quality data from 2001-2016 was accessed from the Department of Water and Sanitation's public online resources to frame the snapshot data and flag any negative changes over time (DWAF N.D. accessed June 2017). The historical data was taken from below the Vaalharts Weir and downstream of the Taung Dam for comparative inflow values and at Lloyds Weir on the Harts River for return flow trends.

Significant differences in spatial and temporal variation of the water quality variables were determined through a one-way analysis of variance (ANOVA) in GraphPad prism 5. Data were tested for normality through the use of the Kolmogorov-Smirnov test ($p < 0.05$). Significant differences were tested if $p < 0.05$, with the use of the Tukey's post-hoc statistical analysis test. Kruskal-Wallis post-hoc test was performed if data were not normally distributed (methods adapted from de Klerk et al. 2012). Percentiles (50th and 95th) of available constituents from DWAF historical data were calculated and plotted on graphs with averages of the seasonal values of the snapshot data.

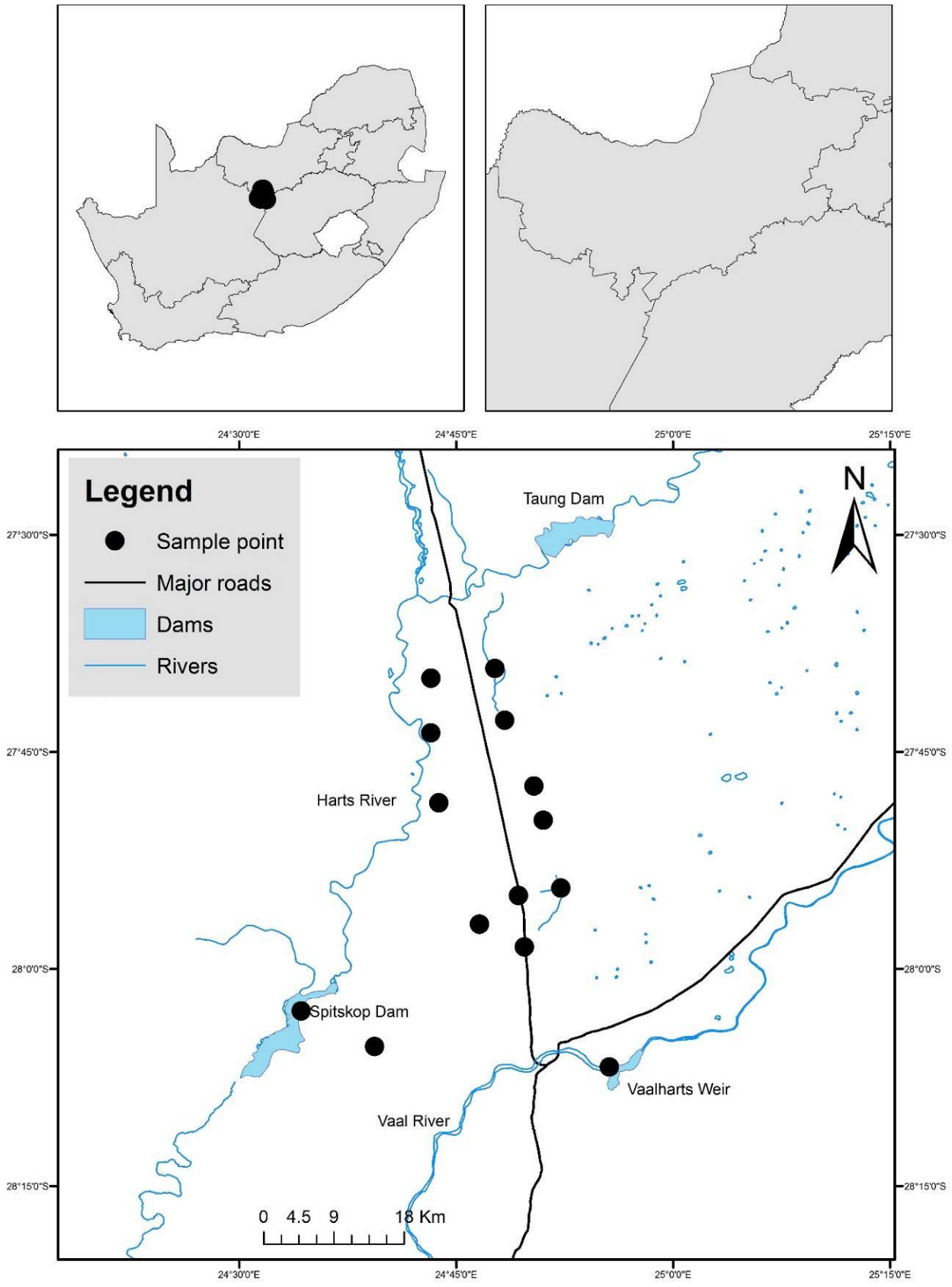


Fig. 1 Map of sample points along the Vaalharts Irrigation Scheme that were used for water quality collection March 2016, May 2016, July 2016, September 2016, November 2016 and January 2017

The South African Water Quality Guidelines for Irrigation (hereby referred to as WQGI) describes the appropriate range for water quality according to target water quality range (TWQR) (DWAF 1996). Where necessary this study accessed the FAO guidelines (Ayers and Westcot 1994).

The ranges are classified as:

1. Ideal (below the TWQR).
2. Acceptable (closer to the TWQR).
3. Tolerable (limited time period of use recommended as the levels are close to the TWQR).
4. Unacceptable (above the TWQR).
5. Completely unfit for use (very much above the TWQR).

3. Collection and analysis of qualitative data of farmers' perceptions

Farmers (N=12) were selected for semi-structured interviews based on their geographic distribution along the scheme and use of irrigation water from the Vaalharts Irrigation Scheme. Interviews were conducted in English, Afrikaans or SeTswana with small (n=4), medium (n=4) and large (n=4) scale farmers. Small scale (SS) farmers were mostly situated in the community of Ganspan with plots of 0.6 hectares (Ha) (Hashe et al. 2008). Medium scale (MS) farmers were those also termed "emerging farmers", three of which were part of government-supported programmes and farming on plots of 25 Ha and up. Large scale (LS) farmers were determined as larger producing commercial farmers independent of government projects with combined plots bigger than 25 Ha. The interviews followed an interview protocol and were audio recorded for verbatim transcriptions. Where necessary, a translator was used.

Guiding questions in the protocol were:

1. Let's talk about water quality, what comes to mind when you hear the term water quality? Probes included specifics about the Vaalharts Irrigation Scheme and the effect on crops.
2. When you think back over the past years what have you noticed about the quality of water? Probes included asking for examples, causes and consequences of these changes.
3. What is your opinion of the effect of water quality on local food security? Probes include asking for examples.

Transcripts from the semi-structured interviews were analysed thematically using ATLAS.ti software. The guide by Friese (2014) provided the technical know-how on the use of computing software and the theoretical steps involved, from noticing, grouping and analysing codes.

4. Integration of data

The water quality data from the quantitative analysis and the recommended mitigation methods suggested by the national guidelines on WQGI (DWAF 1996) were tabulated against the farmers overall perceptions of water quality, perceptions of specific key constituents and their mitigation methods.

5. Validity, reliability and qualitative trustworthiness

Quantitative data collection followed set protocols that the researcher was trained in prior to commencement. The sites for collection were geographically dispersed across the scheme and divided between the weir, inflow and outflow canals, providing a reliable representation of the scheme. Supervision from members within the Water Research Group of the North-West University was provided during laboratory analysis.

Trustworthiness was guided by the four epistemological standards as proposed by Lincoln and Guba in Botma et al. (2010). *Credibility* was maintained through prolonged engagement, as there was familiarity with the community gained throughout a period of a year. Training on interview techniques was conducted by the project leader prior to commencement of data collection as well as member checking as the interviews progressed. *Transferability* or applicability was upheld by the sample choice as the study was case-specific and the participants fulfilled the inclusion criteria. *Dependability* was gained through the description and adherence to protocol. In terms of *confirmability,* field notes were recorded to ensure reflexivity and neutrality were maintained by an audit trail and triangulation with the quantitative data set.

This study received ethical clearance from the North-West University; ethical number NWU-00351-15-A1 in accordance with the Helsinki Declaration (World Medical Association 2013).

3 Results

1. Water quality of the Vaalharts Irrigation Scheme

Selected variables were described in terms of their classification, consequences and historical trends. A wide range of variables were analysed but only selected parameters of importance will be discussed. The full range of variables analysed are presented in Table 1 but results and discussion focussed on selected variables that were highlighted from the qualitative questionnaires.

Total dissolved solids (TDS) is classified as tolerable for irrigation use at inflow and outflow levels as both exceeded the minimum range suggested by the FAO, but were within the TWQR (Table 1). The EC, which is related to TDS is considered unacceptable as it exceeds the TWQR of 400 µS/cm by 307 µS/cm and 621 µS/m respectively that is suggested by the WQGI (Table 1). The inflow data for TDS/EC were below the 95th percentile of historical trends but above the 50th percentile, therefore showing that water coming into the scheme had increased in salinity over time in terms of TDS/EC. Outflow data for TDS/EC were however below both historical percentiles (Fig. 2). Although there were discrepancies between the TDS and EC ranges, both follow the same trend when looking at seasonal data (Fig. 2). Sodium levels were acceptable for the inflow concentration but only tolerable for the outflow value (Table 1). Inflow readings varied seasonally above the historical 50th percentile but remained below the 95th percentile. Outflow readings were below both historical percentiles (Fig. 2). Potassium was unacceptable for both inflow and outflow values, measuring 8.1 mg/L and 7.6 mg/L higher than the TWQR (Table 1). Plotted

against historical data, it appears that these values were not atypical and both inflow and outflow values were below the 95th percentile and were consistent with the 50th percentile (Fig. 3).

Exceeding the TWQR for both inflow and outflow readings, pH was classified as tolerable (Table 1). Against historical data, both inflow and outflow readings were above the 95th percentile, showing that pH levels have been increasing over time (Fig. 2).

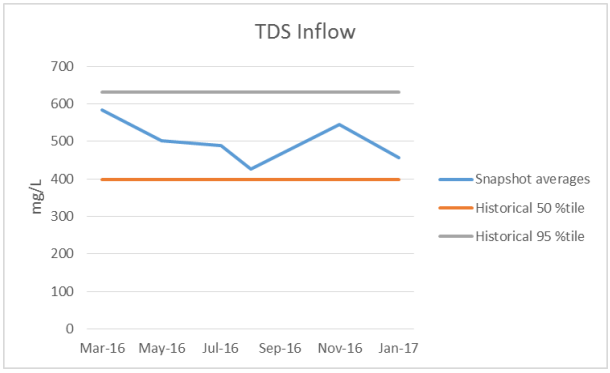
Phosphates and nitrates were both rated as ideal for inflow and outflow values (Table 1). Plotted against historical data, there was an indication that concentrations have increased over time with both phosphates and nitrates peaking above the 95th percentiles for inflow and outflow data (Fig. 3).

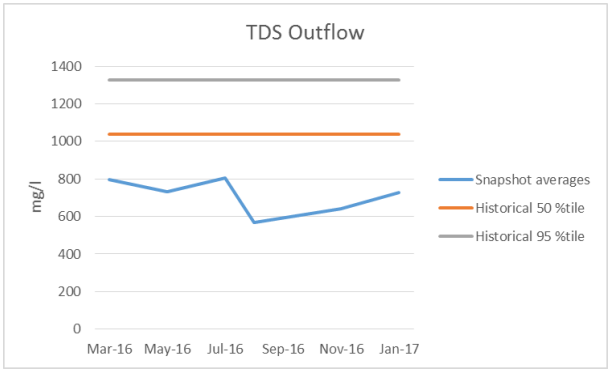
Metals were all classified as ideal for inflow and outflow values, with only manganese adjusted to acceptable for outflow readings (Table 1).

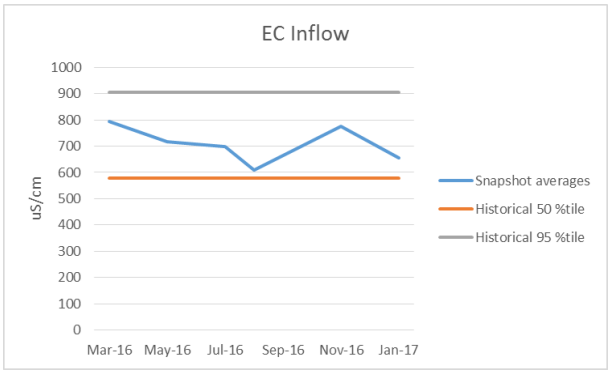
The water quality was classified as fit for agricultural use but with caution to observe tolerable and unacceptable levels of TDS/EC, pH, Na and K and to apply suggested mitigation techniques. Differences between inflow and outflow results were significant for TDS/EC, Na, NO_3 and Cl where an increase in measurements was noted for outflows.

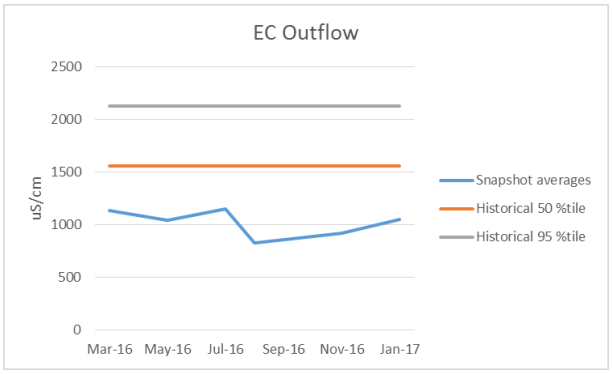
Table 1: Mean values, standard error, TWQR and fitness for use of key constituents, nutrients and metals in the irrigation water from the Vaalharts Irrigation Scheme sampled from March 2016 to January 2017.
* Ranges taken from the FAO guidelines (Ayers and Westcot 1994)

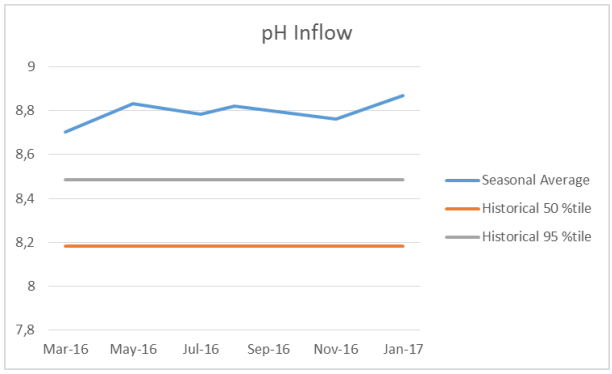
Water Quality Indices						
Key Constituents						
Variable	**Unit**	**Weir**	**Inflow**	**Outflow**	**TWQR #**	**Fitness for use Inflow/Outflow**
TDS	mg/L	495 ± 17	501 ± 9	712 ± 36	450-2000*	Tolerable
EC	uS/cm	721 ± 33	707 ± 12	1021 ± 51	400 (40 mS/m)	Unacceptable
pH	-	8.8 ± 0.066	8.8 ± 0.035	9.1 ± 0.070	6.5 – 8.4	Tolerable
Na	mg/L	48.45 ± 7.96	53.76 ± 2.39	74.46 ± 5.64	70	Acceptable/tolerable
Turbidity	mg/L	32.83 ± 8.67	34.36 ± 4.55	39.31 ± 4.39	50	Acceptable
Po_4^{3-}	mg/L	0.260 ± 0.080	0.223 ± 0.241	0.221 ± 0.034	0-2*	Ideal
NO^{3-}	mg/L	0.330 ± 0.068	0.773 ± 0.099	2.686 ± 0.474	0-10*	Ideal
NH_4^+	mg/L	0.168 ± 0.053	0.177 ± 0.037	0.186 ± 0.035	0-5*	Ideal
SO^4	mg/L	194.0 ± 0.0	175 ± 13.16	193.4 ± 13.24	0-960*	Ideal
Nutrients						
P	mg/L	0.257 ± 0.112	0.179 ± 0.025	0.191 ± 0.026	0-2*	Ideal
K	mg/L	8.719 ± 1.407	10.08 ± 0.463	9.636 ± 0.477	0-2*	Unacceptable
Zn	mg/L	0.012 ± 0.007	0.004 ± 0.001	0.004 ± 0.0005	1.0	Ideal
Cl	mg/L	46.00 ± 20.00	62.00 ± 10.9	91.80 ± 14.72	100	Acceptable/tolerable
Ca	mg/L	32.90 ± 2.809	33.60 ± 1.202	42.81 ± 3.142	0-400*	Ideal
Metals						
Al	mg/L	0.005 ± 0.002	0.003 ± 0.0004	0.003 ± 0.0006	5.0	Ideal
Mg	mg/L	17.67 ± 2.554	19.44 ± 0.767	34.11 ± 3.132	0-60*	Ideal
V	mg/L	0.004 ± 0.005	0.003 ± 0.0002	0.006 ± 0.001	0.10	Ideal
Cr	mg/L	0.001 ± 0.0003	0.001	0.002 ± 0.0002	0.10	Ideal
Mn	mg/L	0.002 ± 0.001	0.003 ± 0.002	0.033 ± 0.031	0.02	Ideal/Acceptable
Fe	mg/L	0.054 ± 0.011	0.052 ± 0.004	0.073 ± 0.010	5.0	Ideal
Co	mg/L	0.001 ± 0.0001	0.001	0.001	0.05	Ideal
Ni	mg/L	0.004 ± 0.001	0.005 ± 0.0002	0.004 ± 0.0002	0.20	Ideal
Cu	mg/L	0.005 ± 0.001	0.004 ± 0.0004	0.005 ± 0.0005	0.2	Ideal
Se	mg/L	0.003 ± 0.001	0.003 ± 0.0004	0.004 ± 0.001	0.02	Ideal
As	mg/L	0.002 ± 0.001	0.002 ± 0.0002	0.002 ± 0.0002	0.1	Ideal
Mo	mg/L	0.003 ± 0.001	0.003 ± 0.0002	0.003 ± 0.0002	0.01	Ideal
Cd	mg/L	0.0004 ± 0.0001	0.0004	0.0005	0.01	Ideal
U	mg/L	0.002 ± 0.0002	0.002	0.002	0.01	Ideal
Pb	mg/L	0.003 ± 0.0007	0.002 ± 0.0002	0.002 ± 0.0002	0.2	Ideal

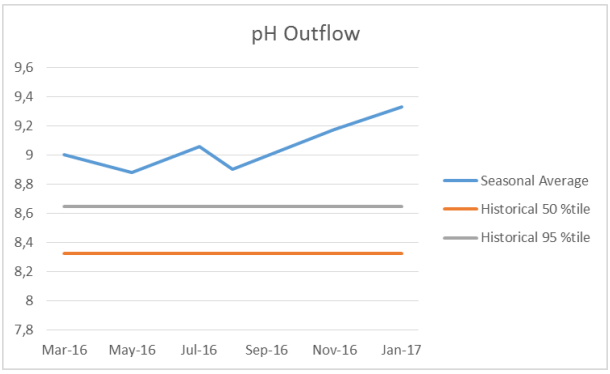


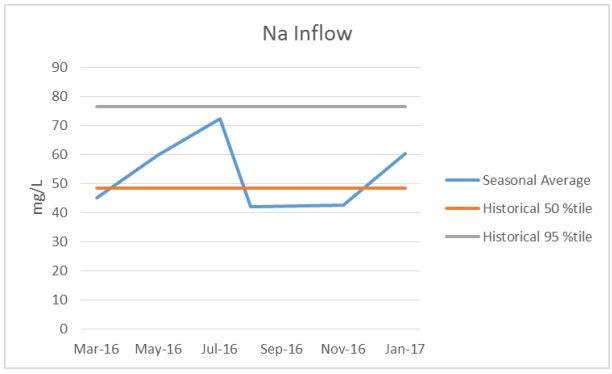












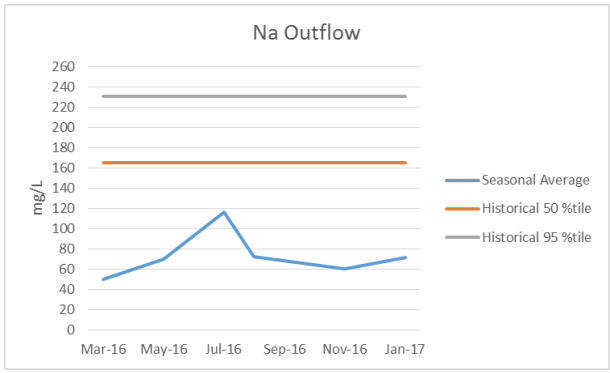
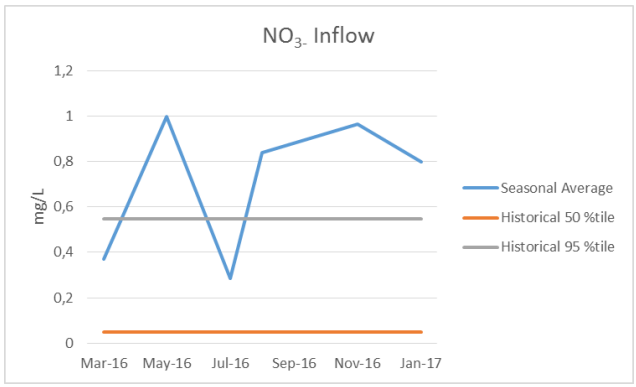
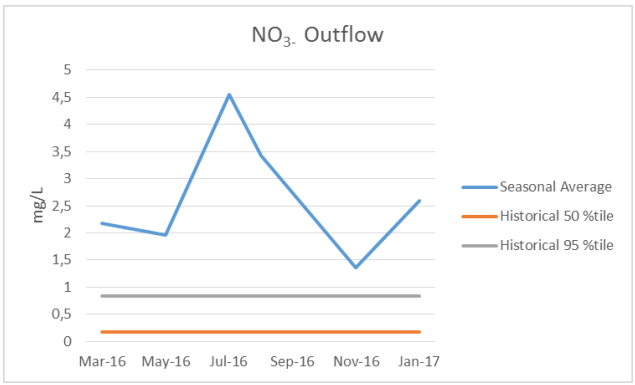
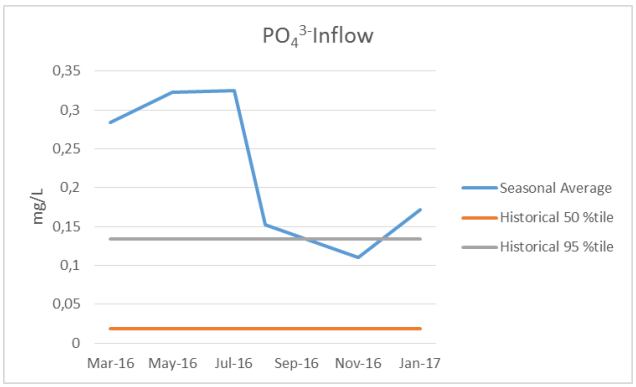
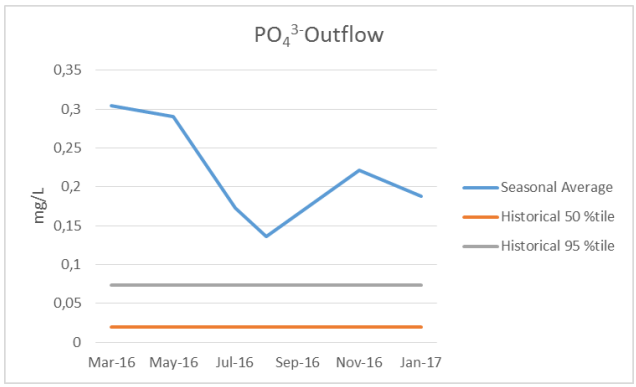


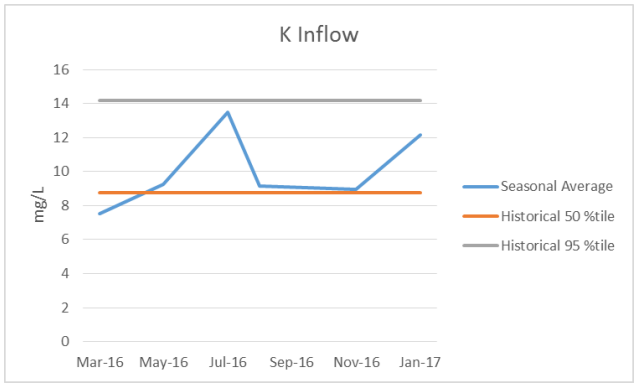
Fig. 2 Inflow and outflow measurements of selected constituents from the Vaalharts Irrigation Scheme from this study collected from March 2016 to January 2017. The 95th and 50th percentiles of historical DWS data are included for comparison.











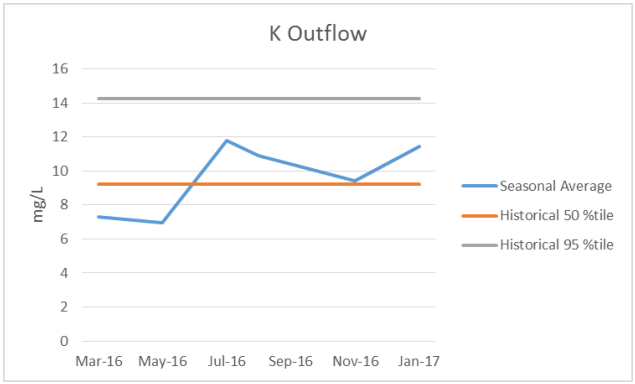


Fig. 3 Inflow and outflow measurements of selected constituents from the Vaalharts Irrigation Scheme from this study collected from March 2016 to January 2017. The 95th and 50th percentiles of historical DWS data are included for comparison.

2 Farmers' perceptions of irrigation water quality

Farmers expressed they did not know the exact state of the water and that having that knowledge would help production. Despite their perception of a lack of knowledge, they displayed a practical knowledge based on their sensory observations and farming experience. Other avenues of knowledge transfer included generational, agricultural education, interactions in the farming community and training through governmental departments. Negative perceptions of water quality were evident among all farmers (Table 2).

In describing water quality, farmers would use the comparison between irrigation water and rain water, expressing that rain water was good because it was natural, uncontaminated and contained nutrients. Rain was also rated highly because it is linked to the availability of water.

> *"The rainwater is also good, it helps a lot. Rainwater is natural water, things grow, and our plants grow. Like I just plant, I planted seedlings a few days before it rained they have sprung up like nobody's business (laughs)."* (SS Farmer)

Sensory observations shared by the farmers included the visual attributes of the irrigation water, affirming that a dark colour meant poor quality and indicated the presence of algal blooms and sewage foam as well as the presence of rubbish and dirt in the canals. Farmers also complained of bad odour, particularly in times when irrigation dam levels were low and the water had been flowing less, and that this was an indicator that the water quality was poor.

> *"We can see, as farmers, the only measurement we use is we can see the water is dark, (there is a) stench, or you can smell the water is bad and then we know this time of year we didn't have good rains and there is no water flow in the rivers. When we get to our dams and we can smell and see the water quality you can see if it is not a good quality."* (LS farmer)

These aesthetic attributes were combined with a sentiment that water was a health risk to people and that perceived lack of potability was an indicator. There was a concern about the safety of swimming in the farm, or municipal dams and canals, with examples of people getting rashes as supporting evidence.

> *"I think good water quality is water you can drink, I think that is the bottom line. Further I can't elaborate sorry, because even our borehole water is no longer potable, well it is potable, but for example our borehole is high in nitrates, so we must put in filters to take it out."* (MS Farmer)

Crop health and yield were used as indicators of poor water quality and the incorrect levels of constituents such as salts, pH and metals was seen to affect food production. Examples given by farmers included leaf colour and spots as well as the size of the produce. Water quality, according to farmers, inhibits growth rate, crop health, food quality and marketability. Additionally, alterations in crop choice in response to poor water quality were mentioned, although not stating which crops were more tolerant. Farmers highlighted that water quality affects soil health and availability of

nutrients from soil and that although water quality may affect the yield, it is difficult to measure its impact.

> *"It actually dies off, it dies off, it just doesn't grow, it goes yellow, it will germinate, but that also depends on the grade of brackishness, in that piece of soil."* (LS Farmer)

The farmers who felt positive about the water quality (mainly SS farmers) (Table 2), claimed that the water was of suitable quality as their crops are thriving.

> *"…but you know what I think if the water is not good, not having a good quality, our plants would not grow, they would not be growing nicely, but now they are growing, I don't see any problem with water."* (SS Farmer)

Farmers used examples from the environment such as presence of lesions on fish or a decline in aquatic life in the region as indicators of water quality. Some farmers stated that if the water was not healthy for people, it would not be good for plants either. Those positive about the water quality also used the environment as an indicator, stating that livestock and aquatic life were not affected and therefore the water is suitable.

> *"It is just like let's say if we drink dirty water it will affect our health (laughs). That is why I say the production will be affected. I mean as individuals we can't drink dirty water, it will affect our health and we will become sick. The plants will also have a problem."* (SS Farmer)

The farmers were conscious that the location of the scheme resulted in the water quality being influenced by mining, sewage and industrial activities upstream. It was mentioned by one farmer that farming activities, including fertiliser leaching and runoff from livestock and dairy farms, contributed to poor water quality. The fact that the canals are exposed was also a concern for farmers as the risk of additional dumping of rubbish and old poison containers along the scheme could influence water quality negatively. The canals were seen as a mode of transport for unwanted weeds and litter in the lands.

> *"I mean, there have been instances where factories have been caught out dumping their waste in water, so we don't know really what is factored in that is not natural with the waters."* (MS Farmer)

Water availability was a common theme from the farmers who naturally attributed the success of food production to water as a necessary resource. More specifically, water availability could be impeded by people through mismanagement of water scheduling, the state of canals and drainage systems, controlling payment deficits and policing the canal system. Natural impediments were confined to tree roots or rocks blocking the canals which would become a maintenance issue.

> *"Yes, here in front of us you get the canals, full of rocks, and bottles and papers. They throw anything there, and children are also playing there. We are not (talking) badly of the*

children, but we fight over the rocks because the canals become filled with rocks, the water flows a bit less and you get less water. The people measuring the water tell us we receive a certain amount and now sometimes you don't get enough." (SS Farmer)

Additionally, farmers emphasised the role of infrastructure management in ensuring water quality and maintenance. The onus of responsibility was placed mostly on the municipality at a provincial or national level, on the Vaalharts Water Association and, to a lesser extent, on the community and people. Individual farmers would be involved with periods of cleaning the canals of unwanted organic matter and obstructions but generally the responsibility was considered to be external to farmers. There was mention of the support of co-operatives in settling concerns of acid mine drainage or by providing water quality information. In terms of water quality, farmers expressed that the relevant departments should make sure that those maintaining/treating the water should have the right expertise for the job. In terms of policing misconduct along the irrigation scheme as well as pollution upstream, it was noted that legislation is in place but it was not followed through with fines and adherence to the laws.

"Like I said now, like the municipality, ne? If their sewage comes in the river there should be a big fine issued to them, because they are simply not doing their work that is all. I mean that stuff that happens today shouldn't happen." (LS Farmer)

More farmers spoke on the decline in water quality over time, with very few confirming that there was no change. There was a trend of increases in the historical data for TDS/EC, pH and fluctuations in sodium, nitrates, phosphates and potassium (Figs 2 and 3) which indicate a possible decrease in water quality over time. Examples of changes over time included declining yields and the need for more agricultural inputs to get the same quality produce. Additionally, farmers mentioned that issues such as dumping in the canals and the presence of weeds that had not thrived before were indications of the decline in water quality. Dumping in the canals and the quality of the water was attributed to a failure in municipal management.

"I mean a company like Monsanto, they used to have farmers here plant seed maize, and since last year or the year before they said they won't even, because of the yield I mean, they invest all that money but the crops don't yield anymore, although they get the water, so if they get the water and it doesn't grow then what is wrong?" (MS Farmer)

Examples of having to change crops over the years were given as well as the notion that farmers have had to be adaptable due to fluctuations in water quality.

"In my school days, the farmers in Vaalharts planted tobacco and there were some who became rich from tobacco, but the companies wouldn't buy the tobacco later on because the chlorine composition in the leaves was too high and that killed the tobacco industry in Vaalharts, the people couldn't plant it." (LS Farmer)

Farmers who denied any changes over time did so due to consistency in crop health and harvest.

"The water is still the same because we see it in the food we plant, the food hasn't changed because we have just one method." (MS Farmer)

Table 2: Overall perceptions of water quality, food production and food security collected from farmers along the Vaalharts Irrigation Scheme during 2016/2017

Farmers	**Overall Perceptions**					
	Positive water quality	Positive food production	Positive food security	Negative water quality	Negative food production	Negative food security
Small (n=4)	XXX	XXX	XX	XXXX	XXX	X
Medium (n=4)	XX	XXX	X	XXXX	XXX	X
Large (n=4)	XX	X		XXXX	XXXX	XXX

X = the occurrence of the respective theme per interview

3 Integration of water quality measures and farmers' perceptions of water quality

As the water was deemed fit for agricultural use in spite of the concerns over influences, it may seem there is a gap between the farmers who expressed negative perceptions regarding the water quality and the actual water quality from the Vaalharts Irrigation Scheme. However, when looking into the perceptions regarding specific constituents, predominantly salts, their sentiments may not be misplaced. In order to integrate the results, the water quality analysis (overall state and specific constituents), recommended mitigation from the WQGI (DWAF 1996), farmers' perceptions of water quality and their actual mitigation methods are depicted in Table 3.

When discussing overall perceptions of water quality that were considered as negative, farmers described certain remedies or mitigating actions to improve crop health such as installing oxygenation pumps and additional fertilisers or folio sprays (Table 3). Although the water quality is fit for agricultural use, there were constituents classified as acceptable, tolerable and unacceptable (Table 1). The recommendation from the WQGI would then include monitoring of prolonged irrigation use. However, the farmers did not state knowing the exact levels of constituents they were mitigating for.

3.1 Salinity

Farmers were aware of the impact of salts, describing how salinity affected their crops; that it inhibited the osmotic potential of water and that growth was stunted. They noted the yellow colour of the leaves rather than green, and that plants would be shrivelled. As TDS/EC was classified as tolerable and unacceptable, the farmers' perceptions were in line with the WQGI description of the typical stress reaction of plants to salinised water that is similar to plant drought responses (DWAF 1996). According to the WQGI, the way to mitigate for TDS/EC in this range includes changing crops, improving drainage and diluting the irrigation water; methods paralleled by farmers when discussing mitigating methods (Table 3). In line with the WQGI, farmers noted that good drainage was necessary and would help with minimising water logging. However, the WQGI do not suggest additives such as lime, gypsum and the additional fertilisers as mentioned by the

farmers. One farmer discussed adapting to sustainable farm practices in order to increase the carbon content of the soil so as to improve soil salt levels. However, the WQGI do not suggest these practices but rather, suggest the intensification of annual crops. There are suggestions in the WQGI that refer to irrigation practices; increased irrigation, higher frequency of irrigation and only using irrigation as supplementing rainfall to remedy TDS/EC levels in this range, as desalination is considered an expensive process (DWAF 1996). Some of the farmers did mention mixing borehole water with irrigation water.

The farmers did not mention sodium but it was classified as acceptable and tolerable and a number of mitigating measures for this range that were similar to TDS/EC were provided by the WQGI. None of these techniques were mentioned by the farmers (Table 3). Potassium was also not considered problematic by the farmers, although potassium levels were unacceptable. Potassium does not feature individually in the WQGI. Along with sodium, it is associated with TDS which farmers were concerned about.

3.2 pH

The pH is in the tolerable range but was of concern as it was above the TWQR for both inflow and outflow measurements. The pH was not as prolific a concern among the farmers, with only three farmers discussing pH. Those who were concerned mentioned the inhibiting nature of a high pH on micro-nutrient uptake (LS Farmer) and attributed plant health and undesirable leaf colour to pH (SS Farmer). pH in this range has an effect on the uptake of micronutrients such as zinc while a higher pH on irrigation systems is mentioned in the WQGI. The use of acidifiers to lower the pH levels is recommended. Additionally, how fields are irrigated could help remedy the effects of a higher pH such as pivot height. The implication on water use for pH in this range is that switching the type of irrigation components may be necessary if using a pivot or drip irrigation. The only mitigating method to neutralise undesirable pH levels that the farmers mentioned was the use of fertilisers (Table 3).

3.3 Nutrients

Phosphates and nitrates were at acceptable and at ideal levels and may not be a concern for farmers due to the positive attributes of both to plant growth. Nitrogen was considered positively, with just one mention that accumulated nitrogen would damage a new crop if crop rotation is not used (MS Farmer). Nitrates are influenced by fertiliser use and this should be kept in mind by farmers (DWAF 1996). Of the mitigation measures that were used by farmers and are in line with the WQGI was the use of filters to keep out organic matter which may be due to algae growth (Table 3). There are no recommended mitigation techniques for phosphates, although improved drainage was considered by a farmer as a mitigation technique.

3.4 Metals

Effluent from industry and mines was a concern for farmers as contributing to influences on poor water quality, due to the activities upstream (WRC, 2016). However, metals were still within the ideal range. The WQGI for the majority of metals if they were problematic would include the use of lime as a pH control to counter the effects of the metals. Phosphate fertilisers counter copper,

while gypsum can be used for fluoride. These are additives mentioned in general by famers but there were no mitigation techniques mentioned that were mentioned specifically for metals.

Table 3: Integration of water quality, recommended mitigation techniques*, farmers' perceptions and farmers' mitigation methods

Integration of quantitative and qualitative results				
	Actual water quality	**Recommended mitigation techniques* aligned with farmers techniques mentioned in the study**	**Farmers' perceptions**	**Additional mitigating techniques used by Vaalharts farmers, drawn from qualitative data analysis**
Overall water quality	Fit for irrigation use	–	Negative perception of water quality	– Oxygenating the water – Using filters on pumps – Adding stimulants – Folio sprays and fertilisers
TDS/EC	Tolerable/unacceptable	– Switch to crops which are more salt tolerant. – Install artificial drainage. – Diluting irrigation water with alternative sources	Salts were perceived an issue, attributed growth problems to salinity	– Planted alternate cultivars – Using lime and gypsum – Testing the soil – Using "sugar" – Raising the carbon content through sustainable agricultural practices.
pH	Tolerable	–	Not considered problematic	– Being advised on which fertiliser to use
Sodium	Acceptable and tolerable	–	Not mentioned	–
Phosphates	Acceptable	–	Not considered problematic	– Improved drainage
Nitrates	Ideal	– Use filters to remove unwanted algae and water plants	Not considered problematic	–
Metals	Ideal	–	Cited effluent from mining and industries upstream as major influences.	–

*Recommendations provided by the national water quality guidelines, according to the ranges of the constituents (DWAF 1996).

4 Perceived linkages between water quality, food production and food security from Vaalharts farmers

Large scale farmers perceived the state of food security negatively (Table 2) due to constraints in water availability, the impact of drought and the decline in yield of grains. Other constraints in production include lack of government support, rising input costs (e.g. electricity to run pumps) and the pressure of debts. There was a concern that there was a decline in agriculture as a profession, while at the same time there is no appreciation by the consumer of the role of the farmer. Additionally, the market system was an issue for farmers in that even if food was sufficiently available, there was a gap in the local food system that did not include processing

while on a national level there was a perception that trade agreements lead to exporting higher grade products and buying back grains from other countries, a problem which leads to higher food prices.

Table 2 shows that although farmers were generally negative about water quality, it was the SS and MS farmers who expressed positive perceptions. Similarly, positive perceptions of food security were expressed by the SS and MS farmers.

Of the four dimensions of food security, it was mostly the availability and stability dimensions that were linked to water quality by the farmers. Farmers expressed that food production, which is inherently linked to the availability dimension, would not only be impacted by land and water availability but also by the ability of these resources to produce. Water quality affects the amount of water needed, the type of crop planted and the overall growth performance and yield as well as the health of the soil.

> *"That factors of production do not impede production, they become so expensive that emerging farmers cannot participate in food security. For me, that is what it is."* (MS Farmer)

Water quality was seen to impact stability mainly because declining harvests would impact the decision to continue to farm due to the economic impact on the farmer. There was a sense that without intervention from government, the decline in water quality would continue and in the future, farmers would no longer be able to irrigate from the scheme.

> *"Because if the salts get dire and you get more crops that way that aren't able to grow here anymore, then you will start to realise "ok, what now, am I going to take my things and leave or should I stay here?"* (MS Farmer)

Farmers connected water quality to access and due to the production concerns raised about the effect of water quality on yields, there was a concern that this would not just affect availability but have cost implications for consumers in that more food would have to be imported.

> *"Alright, in Vaalharts, the better the water quality the more we can produce. The quality and the quantity, I would say. If we had a little bit more water we can expand a little bit more. The better the quality the better the yields, the more products we have, so the more food security there would be. So quality and quantity is a big thing for Vaalharts."* (LS Farmer)

A few farmers raised utilisation concerns in that if water is contaminated or toxic due to industry, then it would affect plant health. Water quality could inhibit micronutrient uptake or limit dietary diversity as resilient crops would be planted, further impacting the utilisation dimension.

"…if the water is not good, purified, and it is not clean it will affect our food, because automatically those let's say maybe chemicals or whatever those things that harm our body will get to our food." (SS Farmer)

Discussion

This study investigated the relationship between water quality and food security by integrating a quantitative analysis of water quality from the Vaalharts Irrigation Scheme with a qualitative exploration of local farmers' perceptions regarding water quality and food security. The study was limited in scope in that it was exploratory. The analysis of water quality did not include microbial or coliforms analysis and the concern of farmers regarding sewage could not be compared. Britz and Sigge (2012) have shown that South African rivers are not up to the standard that is ideal for irrigation due to exceeding faecal guidelines. Furthermore, geological aspects and soil dynamics were not expanded upon, nor the toxicity levels of uptake in plants. The study also fell in a period of drought, possibly affecting the weight given by farmers on availability over water quality. Themes regarding farming practices raised a number of additional issues, including water use and the impact of input costs such as labour and electricity as well as political stability and the economic market that could not be followed up further in this study.

Overall, the availability of water, regardless of quality, was a key concern for farmers. As the study is located in an arid region of the country with variable rainfall (Goldblatt 2010), this sentiment is not unexpected. Management and maintenance of the irrigation scheme featured as main impediments to water availability. Additionally, the costs of getting water that was available on to the land was influenced by labour, the use of flood irrigation and by electricity costs for pumps of mechanised irrigation systems. The strong perception of access to water may further be influenced by the political history of South Africa where water distribution was conditional (Perret 2002) and the current shift to a more equitable distribution that as Goldin (2010) suggests, is still marred by power relations, mistrust in the system and a lack of scientific knowledge that may inhibit confronting authorities if there are problems in service delivery. Water availability is further hampered by the increasing effect of climate change that is affecting rainfall patterns in the region (Thomas et al. 2007). Mayilla et al. (2015) also found that water was seen as beneficial, with less regard to quality as availability was more of a priority in Tanzania.

The water quality from the Vaalharts Irrigation Scheme was classified as "fit for irrigation use" with TDS/EC, pH, Na and K levels falling in the tolerable and unacceptable ranges. Despite being classified as fit for irrigation use, farmers were negative about the water quality. Their assessments were based on "real life" experiences, using sensory observation and practical knowledge based on the health and performance of their crops. The combination of salts making up TDS can influence plant growth due to limiting the osmotic ability of the plants, (Van Rensburg et al. 2011) and may lead to crop choices and varieties that are hardier such as cotton and certain cultivars of wheat and sorghum (Qadir et al. 2008) over spinach, for example. Planting alternative crops was a mitigation technique mentioned by farmers. In terms of salinity, the farmers' assessments were more in line with the actual levels. A similar outcome emerged from Carr et al. (2011) study on reclaimed wastewater in Jordan, where perceptions of farmers appeared to be

independent of actual water quality, but when looking at individual constituents, particularly at salinity, farmers' assessments were more aligned. There is caution in prolonged irrigation use without careful monitoring for the range of TDS/EC (DWAF 1996).

There was a lack of concern for other constituents used as indicators of water quality. At the levels measured for pH, there may be problems with damage on the leaves, affecting grading or marketability of crops and possibly yield. Over time, there may be an inhibiting effect of nutrient uptake from the soil level and corrosive problems of irrigation components and encrustation of pipes. Only a few farmers expressed concerns about pH but it may be that these impacts are not as easy to discern as pH issues as with "brackish" water. It may also point to a gap between the farmers' practical knowledge and the way water quality assessments are shared with them. Potassium and sodium levels are referenced separately in the WQGI and were not mentioned by farmers and this may be because they are associated with salinity, which the farmers are concerned about. The constituents are analysed separately but do not function in isolation, for example, higher pH may be associated with salinity (Chapman 1998). Higher pH levels also impact the solubility of metals (Chapman 1998) which may be why metals were ideal, despite mining activities upstream.

Impacts on water quality were generally considered by the farmers to be external to the farm boundaries; mining, sewage, industry, municipal mismanagement and misuse of the canals by dumping. Farm activities such as animal manure and fertiliser run-off into the irrigation system were minimally implicated by farmers as influencing water quality. Despite a concern of eutrophication in South African rivers, as described by Van Ginkel (2011), measures for nutrients were within range, even at return flows.

Only a few farmers noted that sustainable agriculture should be practiced to ensure stability of overall production in the region.

The changes in water quality over time were also attributed to external activities. In terms of salts, according to Smedema and Shiati (2002), salinity of irrigation water in arid regions is expected and there is a reciprocal relationship between salinity of irrigation water and salinisation of irrigated land. Sufficient drainage is one of the mitigation techniques recommended by the WQGI, one corroborated by the farmers who blamed poor drainage in the system on the levels of salts rather than farming itself. The TDS levels assessed may also be attributed to the fact that Vaalharts is one of the country's older irrigation schemes, and, as Armour and Viljoen (2000) indicate, it is not only the impact from the upper Vaal regions but agriculture itself that can degrade the *irrigability* of soil and increase salinity. Directing research, management and farm practices at farm level, according to Van Rensburg et al. (2011), is important when addressing salinity issues in irrigation schemes and that despite being a major concern, salinity can be controlled if appropriate management practices are in place.

Integrating the results is more poignant when aligning the recommended mitigation techniques from the WQGI and those techniques shared by the farmers. Often times, the techniques for mitigating against salinity were aligned but the concern is the addition of inputs such as lime, gypsum and fertilizers that could further exacerbate the salinity levels. Applying inputs or

mechanisms such as oxygenation pumps without knowing the exact levels mitigated for may be an unnecessary cost. The integrated results also showed the lack of concern for pH levels and the possible negative effects of nutrients, even if they were not problematic at that moment. The mitigation techniques shared by the farmers revealed that their actions were guided by their perceptions. These perceptions were driven by their practical knowledge which was passed down through generations, education, gained through interactions in the farming community, shared by governmental departments as well as by their own farming experience. There were techniques used by the farmers that were similar to those suggested by the WQGI that show local knowledge is an asset. Farmers conveyed a willingness to gain more knowledge in terms of water quality or an interest in the topic. Goldin (2010) points out that information sharing can close the gap between non-scientific and scientific knowledge and promote advocacy in water users. A participatory approach to linking local and scientific knowledge has been shown to result in the positive development of technical indicators for soil health (Barrios et al. 2006). Lessons from climate change adaptation however, do caution that the farmers' capacity to adapt should be taken into account (Wilk et al. 2013), for example, adapting farm practices can be hindered by finance and other social problems for small scale farmers, and government support could positively influence larger scale famers (Wilk et al. 2013).

There was a sense of mistrust in the capabilities of those employed to maintain water quality. Management of water availability was however, more of a concern. There may be the expectation that because water is paid for, then this cost includes maintenance and management of the quality. Being more aware of the quality and communicating this across the stakeholders could, in the long run benefit farm production. The concept of water stewardship, as posited by the WWF (WWF 2014), aims to push the agenda of the National Water Act of 1998 that water is a common resource and that the responsibility for its management should extend beyond farm level, in order to benefit the water catchment region as a whole.

Conclusion

Water quality analysis is generally stipulated according to target water quality ranges and is measured according to WQGI rather than set values. In order to have a clear indication of the state of the water, regular testing and monitoring is important as trends can be identified and addressed accordingly. In addition to knowing the quality of water and its effects on food production, integrating the analysis with perceptions of local farmers has proved to be valuable in that their perceptions influence their choice of farm practices, which in turn can have an impact on sustainable water use in the region and food security. Our study showed that although farmers were negative about the quality of irrigation water, this was secondary to water availability. Integrating the data showed that through their practical knowledge, farmers were in line with the salinity concerns flagged in the quantitative assessment.

Including farmers' perceptions in this research revealed that there was an apparent lack of ownership regarding the impact of farming practices on the quality of the water. There were a few farmers who highlighted that sustainable agriculture should be practiced but the overall results showed that farmers pointed to activities upstream or misconduct of the canals within the system

that were external to the farm boundaries. Sustainable agricultural practices are not mentioned in the WQGI and this could be considered if an updated version is compiled.

Due to the multi-faceted nature of food security, government policies, including the NDP 2030 and the NPFNS, aim to boost agriculture as a means to improve rural livelihoods and national food security. Nutrition sensitive agriculture is a useful method of implementing these policies as it includes nutrition education at farm level and stresses the importance of stability and resilience of farming and natural resources (McLachlan and Landman 2013). The research has shown that interventions should, however, be mindful that there are many social, economic and political variables that impact agricultural production and that each community should be treated as case specific. There is a need to reposition the farmer as a pivotal actor within the food security discussion, one that should be supported by governance structures through knowledge exchange and equitable access to resources, and similarly, as one who also has responsibility for the resources used. This should include considering the effects of farm practices on the water quality of the wider catchment area. The water stewardship standard of the WWF (WWF 2014) which translates the National Water Act of 1998 into practice, would help orientate responsibility at farm level by providing a methodology of evaluation and by reasserting water as a common resource nationwide.

The following recommendations have arisen from this study:

1. It is recommended that farmers' local knowledge and observations be linked with scientific knowledge of water quality parameters, in a participatory manner, to develop "on site" indicators for water quality.
2. There is an opportunity to capitalise on the avenues of knowledge transfer and farmers' interest in water quality by monitoring and disseminating regular water quality results that include recommended mitigation techniques. This can be achieved through knowledge fairs that involve various actors involved in water service delivery and agriculture.
3. Through these knowledge fairs, the concept and methodology of water stewardship, as posited by the WWF (WWF 2014), could be introduced in the region to raise awareness and ownership of water quality.
4. It is recommended that farmers' concerns regarding the impact of effluent be addressed by conducting an analysis of coliforms and assessing the faecal range and disseminating these results to the farming community.
5. An assessment of micro-nutrient deficiencies and the relationship to water quality could be performed to further assess the impact on food security in terms of the utilisation dimension.
6. The current Water Quality Guidelines for Irrigation, although comprehensive from a physiological perspective, could be updated and framed in terms of the four dimensions of food security. The suggested mitigation techniques should take into account farm practices that can be adapted to contend with climate change.

7. The focus on food security alleviation in policy, needs to consider the quality and stability of natural resources, including that of water.

Conflict of interest

The authors declare that there is no conflict of interest.

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Section 3: Conclusion and recommendations

3.1 Conclusion

The aim of this study was to explore the relationship between water quality and food security, and essentially it was found that this is a large and complex topic. For the scope of the masters the main objectives were met (Table 3.1). The study showed the possible impact of water quality from the Vaalharts Irrigation Scheme on food production and food security by assessing the TWQR of constituents and integrating these results with farmers' perceptions of what quality. The perceptions of water quality showed that knowledge of water quality and mitigation techniques would benefit food production but that farmers should also take ownership of the quality of water at farm level. Additionally they should be aware of their influence within the water catchment region. The research also showed that there were many social, economic and political variables that impact agriculture and as such any interventions (driven by policy) should treat each community as case-specific.

Table 3.1: Main conclusions of the specific objectives of this study

Objectives		Conclusions
1.	To assess the water quality of the VIS and its potential impact on local food production of small, medium and large scale farmers in the Vaalharts region.	The water quality was deemed fit for irrigation use with caution to monitor prolonged use due to TDS/EC, pH, Na and K. Salinity can impact on crop health and yield due to inhibiting uptake but it can be managed. The pH can affect micronutrient uptake, marketability of crops due to impacts on leaves and may possibly be a corrosive on irrigation systems. Nutrients and metals were not deemed problematic for both inflow and return flows.
2.	To determine the present water quality of the VIS and return flows in terms of priority pollutants and system variables, such as turbidity, pH, salts, and micronutrients.	Salinity: TDS/EC was classified as tolerable and unacceptable. Sodium was classified as acceptable and tolerable. Potassium levels were unacceptable. The pH was in the tolerable range, but was of concern as it was above the TWQR for both inflow and outflow measurements. Nutrients, phosphates and nitrates were within ideal and acceptable ranges. Metals were within the ideal range.
3.	To explore perceptions of water quality among small, medium and large scale farmers of the Vaalharts region and its impact on food	Overall, large scale farmers were negative about water quality with the few positive perceptions expressed primarily by small and medium scale farmers. Similarly, positive perceptions of food security were expressed by a few small and medium scale farmers, whereas large scale farmers were negative.

	production and food security.	Water quality was linked to the availability and stability dimensions of food security. There are linkages to access (due to production concerns and cost) and utilisation (due to diversity of crops and possibility of water based food contamination). Water quality was seen to impact stability primarily as a result of declining harvests which would have impacts on economic stability of farming viability in the future.
4.	To integrate and compare the actual state of the water quality the VIS with farmer's perceptions of water quality	The results were integrated according to the farmers' alignment with the national water quality guidelines in terms of mitigation techniques. The integration of data highlighted that farmers' perceptions of water quality were in line with the salinity concerns flagged in the quantitative assessment. For the individual constituents, there were assessments and mitigation techniques by the farmers that were partly in line with the national guidelines. There were however additional techniques, particularly for salts that may be counterproductive. There was an under-appreciation of the pH levels and an overestimation of metals

3.2 Recommendations and implications for transdisciplinary health promotion

1. Soil and crop samples were collected and analysed, but due to the scope of the Masters format, the results did not form a part of this manuscript. There is opportunity to investigate the relationship between water quality and micronutrient uptake to further ascertain the utilisation impacts of water quality within food security.
2. The study showed that water quality can affect food security which in turn has health implications, therefore raising the possibility of health promotion interventions. This could be facilitated by employing the *intervention mapping for health promotion* steps as laid out by Bartholomew et al. (2011) and applying it to the Vaalharts region to improve communications between all stakeholders and for laying out effective outcomes for sustainable water quality. This recommendation is based on complexity of variables that affect production as indicated by the farmers, as well as the opportunity for aligning scientific and local knowledge for on-site indicators of water quality and the suggestion of "knowledge fairs" that would provide a platform for knowledge sharing.
3. "Water stewardship" could be introduced through the implementation of knowledge fairs to raise 'awareness' and 'ownership' of water quality in the region.
4. Central to the success of health promotion would be a thorough needs assessment and stakeholder involvement from inception. This is further emphasised by the results of this study that showed that policy or action should be sensitive to the uniqueness of each region.

3.2.1 Water stewardship

Water stewardship aims to encourage water users to think about where their water came from, how they use it as an individual and where it is going once they have used it. The 5 steps of water stewardship of the WWF (WWF 2014) as adapted for farmers include:

1. Becoming water aware.
2. Knowing the impact of water use and risks at farm level.
3. Instigating best water practices at farm level and taking action.
4. Start getting involved with water stewardship beyond the farm fence.
5. Contributing to the management of water in the catchment area by influencing governance structures.

The Alliance for Water Stewardship (AWS) provides a practical “standard” or methodology that includes the following stages, in broad (WWF 2014):

1. Commit
2. Gather and understand
3. Plan
4. Implement
5. Evaluate
6. Communicate and disclose

Within the methodology proposed by water stewardship, there is an opportunity for enabling farmers through capacity building, for knowledge transfer and for bettering communities through advocating that water is a common resource as stated by the National Water Policy 1998. These are ideals that are in line with health promotion as set out in the Ottawa Charter (WHO 2016). The steps suggested by AWS align well with the intervention mapping protocol suggested by Bartholomew et al. (2011) for health promotion. Integrating the two methodologies would provide a strong framework for interventions aimed at improving and stabilising the current quality of South African water.

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Appendix

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which I herewith submit to the North-West University, Potchefstroom Campus, is in compliance /partial compliance with the requirements set for the degree:

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RE: EXPLORING WATER QUALITY AND FARMERS' PERCEPTIONS ABOUT WATER AND FOOD SECURITYIN VAALHARTS, SOUTH AFRICA

This serves to confirm that I, Elizabeth Sibanda, undertook the editing of the main body and references of the above-mentioned document on behalf of Aimee Leigh Claassens. I gave Aimee firm changes and recommendations which she applied to improve readability, language and grammar.

Should you have any queries, please do not hesitate to contact me.

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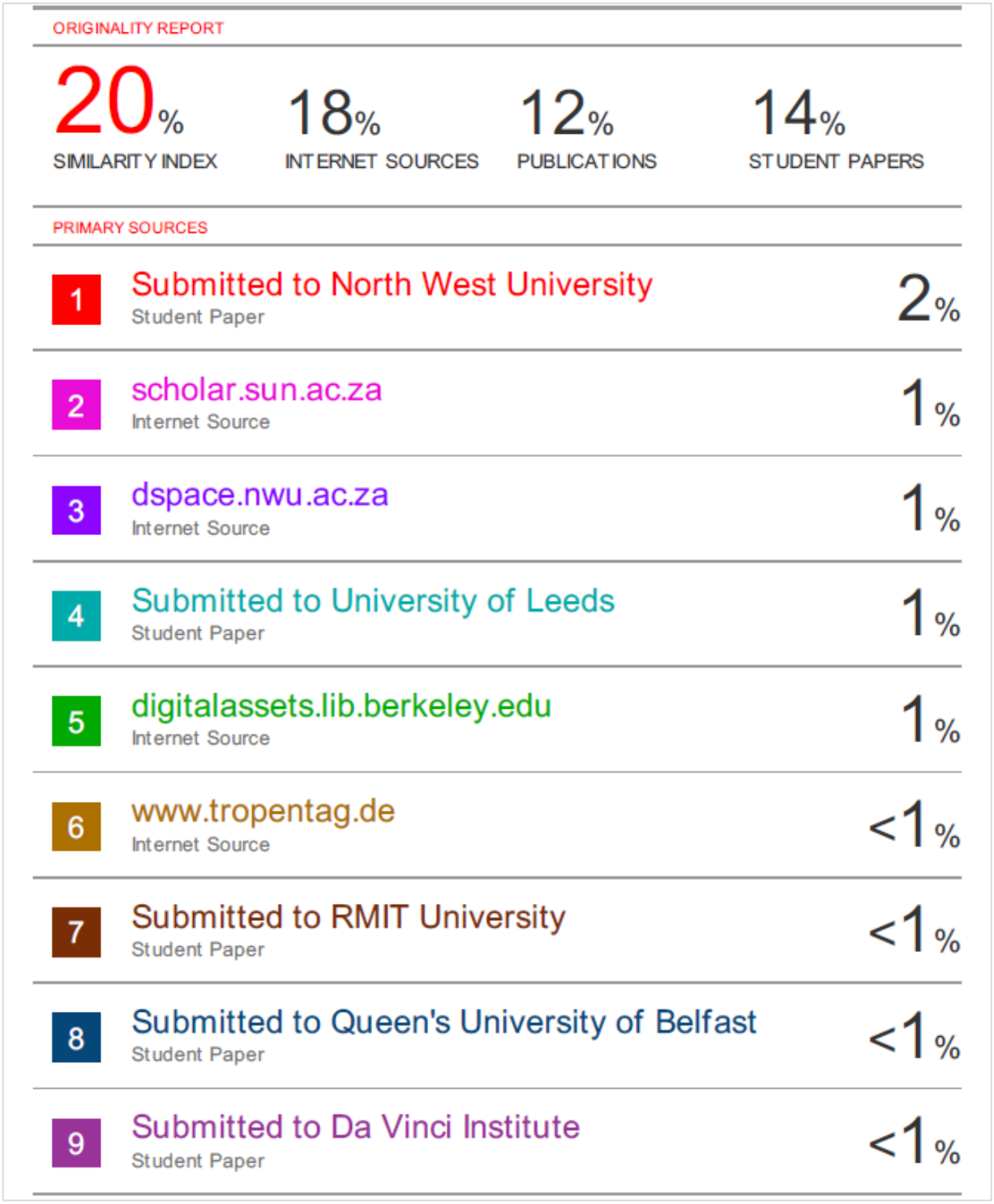

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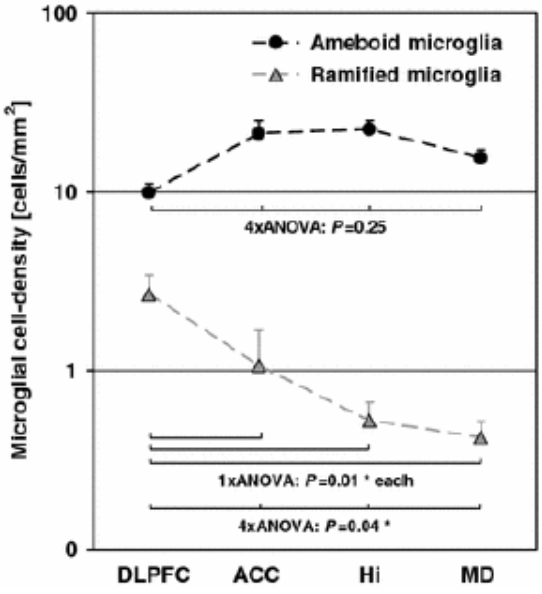

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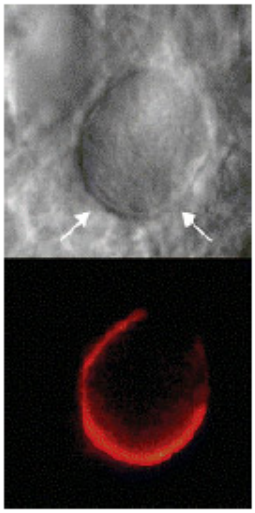

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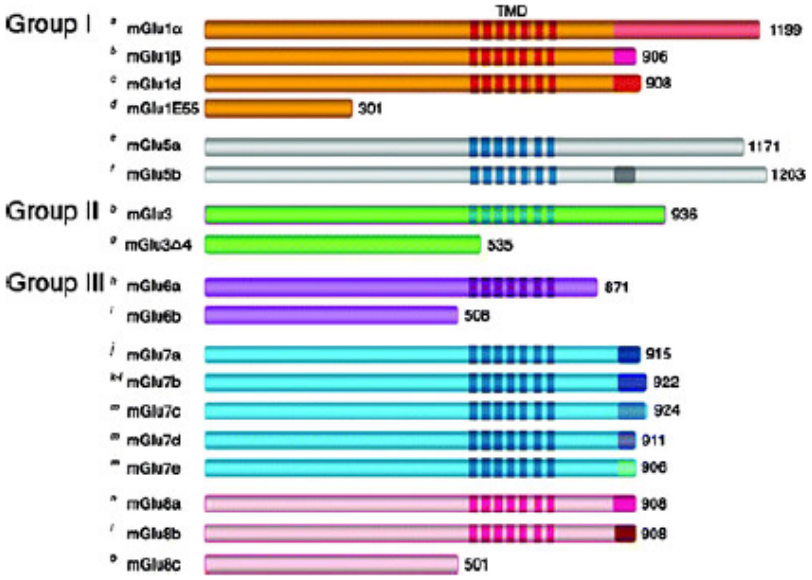

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5. Informed consent

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PARTICIPANT INFORMATION LEAFLET AND CONSENT FORM FOR RESEARCH PARTICIPANTS:

Farmers who participate in the water quality study

TITLE OF THE RESEARCH PROJECT:
The impact of water quality on food production and food security in Vaalharts

REFERENCE NUMBER: NWU-00351-15-A1

PRINCIPAL INVESTIGATORS:
Dr Nicole Claasen, Dr Wynand Malherbe
Mrs Aimee Claassens (student)

ADDRESS:
Unit for Environmental Sciences and Management, School for Biological Sciences, and
Africa Unit for Transdisciplinary Health Research (AUTHeR)
North-West University, Potchefstroom Campus
11 Hoffman St, Potchefstroom 2531

CONTACT NUMBER:
Dr Nicole Claasen: 018 299 2099

You are being invited to take part in this study which is part of the Programme to Support Pro-Poor Policy Development looking into the potential of local food systems on rural sustainable development, led by Prof Annamarie Kruger and Dr Nicole Claasen of the Africa Unit of Transdisciplinary Health Research (AUTHeR) of the North-West University, Potchefstroom Campus. The Programme is funded by the Department of Planning, Monitoring and Evaluation of South Africa in partnership with the EU. Please take some time to read the information presented here, which will explain the details of this project. Please ask the researcher any questions about any part of this project that

you do not fully understand. It is very important that you are fully satisfied and that you clearly understand what this research entails, and how you could be involved. Also, your participation is **entirely voluntary** and you are free to decline to participate. If you say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part.

This study has been approved by the Health Research Ethics Committee of the Faculty of Health Sciences of the North-West University (NWU-00040-13-A1) and will be conducted according to the ethical guidelines and principles of the international Declaration of Helsinki and the ethical guidelines of the National Health Research Ethics Council. It might be necessary for the research ethics committee members or relevant authorities to inspect the research records.

What is this research study all about?

- *This study will be conducted in Vaalharts. We have selected ten farms (small and large-scale farms) according to their geographical position within the Vaalharts Water Irrigation scheme to represent different access of farms to the diverse water canals of the scheme. This study will be carried out by Aimee Claassens, and she will be assisted by local field assistants. I and the field assistants have been trained in general research procedures, sample taking and interviewing skills by our supervisors Dr Wynand Malherbe and Dr Nicole Claasen.*
- *With your permission we will take samples on your farm from four points: 1) irrigation water, 2) soil, 3) different crops and 4) return water. The samples taken once per month over a period of one year (January – December 2016). Samples will be analysed at Potchefstroom Campus with regard to turbidity, salts, metals, selected organic contaminants.*
- *We will carry out face-to face interviews regarding your perceptions of water quality and its impact on food production and food security. We then hope to give recommendations on better environmental considerations for policies and programmes that address local food production and food security.*

Why have you been invited to participate?

- *You have been invited to participate because you are a farmer of food for human consumption in Vaalharts.*
- *You have also complied with the following inclusion criteria: You are older than 18 years, and you are able to speak English, Afrikaans or SeTswana.*
- *You are willing to participate in this study and to be voice recorded during the interview.*
- *You will be excluded if you are below the age of 18; or not an active farmer in Vaalharts.*

What will your responsibilities be?

- *You will be expected to take part in a face-to-face interview where we will talk about your perceptions of water quality and its impact on food production and food security. The interview will take approx. 60 to 90 min. I will try to arragne the meeting at your most possible convenience.*
- *We may contact you for follow-up questions if you allow us to.*

Will you benefit from taking part in this research?

- *There are no direct benefits for you when participating in this study.*
- *The indirect benefits for you as a participant will be a reflection of the environmental sustainability in Vaalharts. This research will raise awareness on these issues among the participants and possibly lead to adjustments of existing programmes or practices. Further, indirect benefits will be recommendations that allow policy makers to better design programmes for better agriculture and food security programmes that link environmental sustainability and local food production to support rural sustainable development.*

Are there risks involved in your part-taking in this research?

- *The risks in this study are minimal. It may be that you experience fatigue or boredom during the interview. You may also experience emotional discomfort when talking about your experiences of water quality issues and its consequences.*
- *The earlier stated benefits of this study outweigh the risk by far due to the low level of anticipated harm and its low level of likeliness of occurrence.*

What will happen in the unlikely event of some form of discomfort occurring as a direct result of your taking part in this research study?

- *We will schedule the interview at a place and time most convenient for you. In case of fatigue or boredom, we will introduce a break and continue when it is convenient for you.*
- If you need a debriefing session with a counselor after the interview, it will be provided free of charge. The principal researchers will organise ad-hoc counselors beforehand.

Who will have access to the data?

- *Your name will never be made known and your data will be handled as confidential as possible. No individuals identifiers will be used in any publications resulting from this study and only the team of researchers will work with the information that you shared.*
- *All information of you, hard copies or audio files, will be protected by locking it up and storing it on a password protected computer, and will only be accessed by the research team.*

What will happen with the collected samples and data?

- *Samples taken from your farm will be analysed at North-West University, Potchefstroom Campus with regard to turbidity, salts, metals, selected organic contaminants. Once tested samples will be discarded according to acceptable laboratory practice.*
- *Hard copy data and digital data of the project will be stored for 5 years and afterwards shredded, deleted and destroyed responsibly thereafter.*

Will you be paid to take part in this study and are there any costs involved?

- *No, you will not be paid to take part in the study but refreshments will be served during the interview. Research procedures will be carried out at a place convenient for you, there will thus be no financial costs involved for you.*

Is there anything else that you should know or do?

- *You can contact Aimee Claasens, Dr Wynand Malherbe or Dr Nicole Claasen (0182992099) if you have any further queries or encounter any problems.*
- *You can contact the Health Research Ethics Committee via Mrs Carolien van Zyl at 018 299 2089; carolien.vanzyl@nwu.ac.za if you have any concerns or complaints that have not been adequately addressed by the researcher.*
- *You will receive a copy of this information and consent form for your own records.*

How will you know about the findings?

- *The findings of the research will be shared with you. You are welcome to contact us regarding the findings of the research. We will invite you to a meeting where we will share the findings with you and welcome your feedback. No information will be shared at these meetings that might cause you any possible loss and/or harm (physical, emotional and financial).*
- *Please be aware that analysis of the data is time consuming and feedback will only be given end of 2016.*

6. Interview Protocol

Research title:

Exploring water quality and farmers' perceptions about water and food security in the Vaalharts Irrigation Scheme

1 Introduction

Date: _____

Time: _____

Location: _____

Name of Interviewee: _____

Special incidences: _____

_____

My name is Aimee Claassens, I am in the process of collecting data for a Master's degree in Health Sciences. The study I am conducting examines water quality in terms of food production, local food security and the perceptions of the farmers of water quality of the Vaalharts scheme. The way the farmer/food grower perceives water quality will be insightful when examined in conjunction with physical sampling (that will be done in the Vaalharts area).

As the expert in this area I would like to share your views; what you see on your land, as well as what you think about the water quality of the scheme and your opinion of the way it may affect food production, local food security and future ecology of the area.

I am interested in your views and thoughts, this is not a test, there is no right or wrong answer. As explained in the consent form, your participation is voluntary and at any point if you are uncomfortable you are free to end the interview.

The interview lasts approximately and hour. With your permission, in order to not miss any detail, may I record the interview? I can demonstrate how it works.

I may make written notes, but this is just a tool for me to really focus on what you are saying.

Everything you will say during the interview will treated confidentially. Names will be blocked out and data will be kept at the North-West University in locked cabinets and digitalised copies will be password projected.

Before we begin do you have any questions?

If you do not have any further questions I would like to begin with the Interview itself.

2 Questions and probes

(1) Let us begin with a brief introduction about yourself and your experience in farming/growing food.

(2) Let's talk about water quality, what comes to your mind when you hear the term Water Quality?

- What about water quality of the Vaalharts scheme, what do you think about that?
- What do you see, can you give examples?

(3) What do you think about the way which water quality can affect the quality of your crops

- Can you provide examples

(4) When you think back over the past years what have you noticed about the quality of water?

- Can you provide examples?
- What do you think could be possible causes
- What do you think could be possible consequences for you and other food producers/farmers of the region?

(5) Let's discuss local food security. What do you understand about the term food security?

- (Can provide definition) Food security can be defined as:
  - *"… a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life"* (FAO, 2003:29).
  - Local in this sense is the Vaalharts area, Jan Kempdorp, Hartswater, Ganspan

- **What is your opinion in which way the quality of water may affect local food security?**
    - access,
    - availability,
    - sustainability
    - utilisation of food
    - Can you provide examples illustrating your answer

(6) From what we have discussed are there any points you think stand out, are important?

(7) If I need to contact you again for a follow up, or more information may I call you again?

3 Thank you and next steps

Thank you very much for your time and answering the questions. This information will be used by me as a student within a larger study to better understand the role of water quality in the Vaalharts area on local food systems. Your contribution is invaluable.