WATER USE and NUTRIENT CONTENT of CROP AND ANIMAL FOOD PRODUCTS for improved household food security: A SCOPING STUDY

Friedeburg Wenhold, John Annandale, Mieke Faber & Tim Hart

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Water Use and Nutrient Content of Crop and Animal Food Products for Improved Household Food Security: A Scoping Study

Report to the
WATER RESEARCH COMMISSION

by

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EXECUTIVE SUMMARY

Many South Africans are affected by malnutrition. This includes overnutrition, with which many adult women present, as well as undernutrition, which is common amongst children. The latter can refer to protein energy malnutrition or micronutrient deficiencies, also called hidden hunger. Previous research has shown that in South Africa the rural poor are disproportionately affected by this double burden of nutrition-related problems. In this vulnerable target group the promotion of home-production of foods that could potentially address their specific nutritional problems, in particular the hidden hunger, appears meaningful. Such interventions should use current food intake and acquisition practices as basis, as well as the reasons for these behaviours. Furthermore, in a country where water may be a limiting factor for home production, the water use efficiency of such crops and animal food products should be known.

In order to account for the complexity of the problem, this scoping study was approached from a multidisciplinary perspective, including human nutrition, social anthropology and agronomy, with the intention to also produce an interdisciplinary output.

In ***Chapter 3*** of the report the results of a comprehensive literature search conducted to identify studies that included information on food intake of rural poor South Africans are presented. From suitable studies data relevant to this study were extracted into a project-specific template. Quantitatively ranked food intake data from these studies are reported, grouped according to geographical area (province) and study.

In KwaZulu-Natal food intake is comprehensively reported at certain sites. For Limpopo Province a number of studies from different sites are available. Food intake in the Eastern Cape, Free State, North West and Western Cape is reflected by a very limited number of studies per province. No quantitative food intake data for rural parts of Mpumalanga, Gauteng and the Northern Cape were identified. The vast majority of studies focused on food intake of individual infants and young children. Non-elderly adults and households were also targeted by a few studies.

In the critical discussion of the findings it was noted that available information cannot be taken as being representative of the food intake of “rural poor South Africans”. On the one hand there were limitations in terms of coverage: geographically, and based on ethnicity / culture and stages of the life cycle. Furthermore, most studies were not designed to describe prevalence. Dietary assessment methodologies used by the various studies do not allow unqualified merging of the findings.

Whilst certain general trends have become apparent, there seems to be insufficient available evidence to compile a single basket of contemporary food intake of poor households in rural areas of South Africa. The preliminary trend that emerged was that current food intake in this group is cereal-based with low intakes of fruit, vegetables and foods of animal origin. In Limpopo Province intakes from green leafy vegetables appear to be higher than the other provinces, and the Western Cape seems to differ from the other provinces in terms of food intake.

Very little information on the sources of the foods consumed by rural South African households was found, resulting in the overall conclusion that there are insufficient data for generalisation. On the national level the National Food Consumption Survey Fortification Baseline (NFCS-FB) of 2005 clearly showed that South Africans *buy* maize, wheat, bread and salt. Purchasing may also be the major mode of procurement for other foods. There is some evidence of home or community gardens, but these do not guarantee an unfailing source of food. Thus for the staple foods purchasing seems to be the most important source, but regarding the foods of which intakes appear to be low (foods of animal origin, fruit and vegetables) and which could potentially be home-produced there is limited evidence of its source, including seasonality.

Chapter 4 builds on the above work on food sources and intake by exploring the reasons underlying or governing food consumption trends among rural poor South African households. This part of the study shows that information on the reasons for the foods consumed by rural South Africans is sparse and fragmented, with only one study really focusing on some reasons for contemporary food choices. Some data were found in studies with other research aims. The data gleaned, and drawing heavily on the framework of Viljoen et al. (2005), allowed for the expansion of this framework that can be used to aid further investigation in this topic. The original framework developed by Viljoen et al. (2005) proposed the following four environmental areas as influencing food intake decision making:

- Physical environment (Determining Availability and Accessibility)
- Economic and political environment (Determining Affordability)
- Socio-cultural environment (Determining Acceptance)
- Individual environment (Determining Individual Choices)

This framework has been expanded during the current study to include the effects of HIV/AIDS and other diseases (including death) on household food choices. These modifications are included in the 'economic and political environment' of the framework, because death and disease will first and foremost result in an economic shock for the household and thus negatively affect the economic environment of the household before changes in other environments are felt. Economic factors (available financial resources and assets, labour ability and household size) will be immediately affected.

Macro and meso level factors tend to influence the decisions made at micro-level. This includes availability, accessibility, affordability, acceptability and household and individual decision making. The reasons for food intake are determined by a range of factors. These include individual, household, cultural and ethnic group preferences, location, season, income and affordability, historical factors, knowledge and education, and social networks, as well as the impact of HIV/AIDS on individuals and households. Therefore micro-level case studies are the best means of understanding the diversity of reasons for food intake. However, most of the existing micro-level studies mention only one or two aspects that are relevant to understanding the reasons for contemporary food intake, as their primary focus tends to be different. More in-depth micro level case studies are required in order to obtain better information on the topic and especially studies that consider the local context, cultural variation, social networks and attempt to prioritise food choices at different times or during different life experiences. Having said that, it is also important to understand how macro level factors (high prices, food distribution, agricultural support services, climate change, etc.) impact on the micro level context and influence local reasons for food intake. It is also important to understand reasons for food intake in different localities at a national level and this could be done by means of including appropriate questions (based on solid fieldwork) into national surveys.

Following a discussion of the principles of the evaluation of dietary quality and an overview of available dietary standards, ***Chapter 5*** outlines the core nutritional problems facing rural South Africans in terms of energy, macro- and micro-nutrient intake as well as dietary diversity and nutrient density. Overall it appears that although several studies have reported low energy intakes, total protein intake was adequate. Gaps in the diet include an inadequate intake of various micronutrients, low nutrient density and lack of variety. Based on dietary as well as biochemical indicators, key micronutrients lacking in the diet are vitamin A, iron and zinc, which relates back to low consumption of foods of animal origin, fruit and vegetables.

It is stated that no single food can ensure nutritional adequacy and dietary quality. Variety, balance and moderation remain the pillars from a nutritional perspective. In addition, availability, affordability and acceptability are essential for a sustainable solution for nutrition (in)security. The process followed to derive project-specific criteria for the compilation of food selection guidance is described, focusing on potentially home-producible foods by the rural poor of South Africa. The list of foods compiled consists of animal-source foods, vitamin A and mineral-rich vegetables and fruit, legumes, stapes, and cabbage as control.

The energy, macro- and micronutrient content of the foods listed in the food selection guidance are presented following a brief overview of food composition data within the process of dietary assessment, with special emphasis on the South African situation. The Chapter ends with a more in-depth discussion of the nutrient composition of two crops: orange sweetpotato and dark green leafy vegetables as a sub-group.

In ***Chapter 6*** a brief review of the principles influencing water use efficiencies (WUE) is given to put into context the published values found in the literature. There is much variation in these values, and limited data for many foods in the food selection guidance. It was not a trivial exercise to quantitatively assess the water use of a crop, or the water needed to produce a unit of animal product. There are many factors that need to be taken into account in order to determine if published values are reliable and can be trusted. Equally many factors affect the efficiency with which water is converted to food, and for this reason, very large variations in published values were found for most food products.

A general ranking of water use efficiency of crop products that ignores water content and composition, from most to least efficient, would be from vegetables to fruits, and on to cereals, oil crops and protein rich legumes. The animal derived products are shown to be less efficient than the crops, and the ranking, again from highest to lowest, is from milk and eggs, to chicken and pork, and on to small stock (sheep and goats) and then beef.

Reliable local "water footprint" data are lacking for most of the food crops investigated, and research is needed on priority foods in areas of need. Research should focus on benchmarking potential yields and water use efficiencies, so that suboptimal performance can be identified, and limiting factors for production or efficiency addressed.

Initial benchmark estimates of nutritional water productivities (NWP) for key nutrients of selected crops (cereals, legumes, fruit, dark green leafy vegetables, and yellow / orange vegetables) and animal food products were made.

Published literature for NWP of crops and animal food products for South Africa is limited, and for many of the items in the food selection guidance no data could be found to make the calculations. The estimates of NWP came from two independent data sources – one a crop water productivity database, and the other a nutrient composition database, both with some level of uncertainty. Of additional concern is the reliability of using these two independent data sets to generate a third database – one of NWP. This is clearly not ideal, but was the only pragmatic approach open to the research team to come up with first order estimates of NWP for important food products.

For all food products there is a wide range in NWPs, probably due to the errors committed with making calculations with two independent data sets – this is problematic, and it is clear that we need to encourage these calculations to be made with single reliable data sets.

In conclusion, this scoping study has mapped the literature available on the topic of water use and nutrient content of crop and animal food products which could potentially contribute to improving the nutrition security of rural poor South Africans through home production. Key concepts in this multidisciplinary approach to addressing malnutrition were identified. Existing evidence from a nutrition, social anthropology and agronomy perspective was presented in the voices of the respective disciplines. Gaps in existing knowledge and research were highlighted and the foundation for discipline-specific and inter-disciplinary follow-up research was laid.

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In chapters 2 and 6 of this report additional authors were involved: Prof Martin Steyn (Department Plant Production and Soil Science, University of Pretoria) and Mr Melvin Nyati (Agricultural Research Council).

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LIST OF ABBREVIATIONS

AEAQ	Average expenditure per adult equivalent
AI	Adequate Intakes
ALV	African leafy vegetables
Avg	Average
BMI	Body mass index; expressed as weight in kg / height in m^2
Ca	Calcium
Cu	Copper
CWP	Crop water productivity
DBE	Department of Basic Education
DDS	Dietary Diversity Score
DGLV	Dark green leafy vegetables
DRI	Dietary Reference Intakes
EAR	Estimated Average Requirement
ET	Evapotranspiration
FAO	Food and Agricultural Organization
FBDG	Food Based Dietary Guidelines
FC	Field capacity
Fe	Iron
FFQ	Food frequency questionnaire
FVS	Food Variety Score
g	Gram
GHS	General Household Survey
HEI	Healthy Eating Index
HI	Harvest index
HIV / AIDS	Human Immuno Virus / Acquired Immunodeficiency Syndrome
HSRC	Human Science Research Council
IES	Income and Expenditure Survey of 2005/2006
IES	Income and Expenditure Survey
IFPRI	International Food Policy Research Institute
IFSNP	Integrated Food Security and Nutrition Programme
IFSS	Integrated Food Security Strategy
INP	Integrated Nutrition Programme
ISRDP	Integrated Sustainable Rural Development Programme
K	Potassium
kcal	kilocalories
kJ	kiloJoules

km	Kilometre
L	Litre
LSM	Living Standards Measure
Mg	Magnesium
MJ	MegaJoule
Mn	Manganese
mo	Month(s)
MRC	Medical Research Council
NAMC	National Agricultural Marketing Council
NAR	Nutrient Adequacy Ratio
NE	Nutrition Education
NFCS	National Food Consumption Survey
NFCS-FB	National Food Consumption Survey – Fortification Baseline
No or n	Number
NSNP	National School Nutrition Programme
NWP	Nutritional water productivity
PEM	Protein energy malnutrition
PPP	Purchasing-power parity
PSNP	Primary School Nutrition Programme
PWP	Permanent wilting point
QFFQ	Quantitative food frequency questionnaire
RDA	Recommended Dietary Allowances
RDP	Reconstruction and Development Programme
SAFOODS	South African Food Database System
SFPS	Sustainable Food Production in Schools
UNICEF	United Nation Children's Fund
WHO	World Health Organization
WP	Water productivity
WRC	Water Research Commission
WUE	Water use efficiency
y	Year
yrs	Years
Zn	Zinc

CHAPTER 1

INTRODUCTION

Friede Wenhold

1.1 RATIONALE AND CONTEXT OF THE STUDY

1.1.1 Theoretical rationale

High prevalences of malnutrition (i.e. undernutrition and overnutrition) have been documented in various national and small scale studies in South Africa. A review of these studies was recently solicited by the Water Research Commission (WRC) (Wenhold & Faber, 2008) as part of another research project (WRC Project K5/1579//4). In general, poor households from rural areas emerged as being particularly vulnerable to nutritional problems, even though the rapid urbanisation and the effects of the nutrition transition on the urban poor (Crush et al., 2011; Ruel et al., 2010) are acknowledged.

The Integrated Nutrition Programme (INP) of the South African Department of Health specifies that prioritisation of nutrition interventions should be based on vulnerability. Vulnerability in official documents is typically defined by geographical areas and / or known nutritional need (Department of Health, 1998) or as any shock or insult that undermines a household's ability to provide sufficient food of adequate quality and quantity for all its members (Ellis, 2003). The above implies that the political will to focus on the rural poor was present at least since the publication of the INP policy in 1998. In spite of this, South Africa is one of the countries with "no progress" in reaching the first Millennium Development Goal (i.e. "to eradicate extreme poverty and hunger"), according to an international landscape analysis of countries' readiness to accelerate actions to address nutrition problems (Engesveen et al., 2009). During the 23rd Biennial South African Nutrition Congress (19-22 September 2010) representatives from the Department of Health stated a continued willingness to scale up nutrition interventions, but argued that political commitment in this regard is "diluted by a poor perception of what nutritional problems are" (Tshitaudzi et al., 2010).

In order to prevent and address malnutrition, the causes thereof need to be known. Broadly speaking, household food insecurity (defined as "limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways" [Bickel et al., 2000:6]) is one of the underlying causes of malnutrition. Food insecurity, in turn, is strongly related to poverty. The current economic climate and rising food prices internationally (Bloem et al., 2010) and in South Africa (National Agricultural Marketing Council, 2009) can be expected to aggravate household food insecurity and malnutrition. In fact, the intricate interrelationship between poverty and malnutrition in South Africa has been described by Vorster (2010) as a vicious cycle. It has been stated that, overall, a healthy diet is unaffordable for many South Africans (Temple & Steyn, 2011), and, even more alarming, it appears that, in general, nutrient rich foods, relative to less nutritious foods, tend to have sharper price rises (Monsivais et al., 2010).

The poor in vulnerable communities may employ coping mechanisms that may adversely affect their nutritional status, e.g. by decreasing the consumption of non-staple foods such as meats, dairy, fruit and vegetables. This will increase their risk for micronutrient malnutrition (also known as "hidden hunger"), which is a public health problem in South Africa and other developing countries. Using international data it has been predicted that, for example, a 50% increase in all food prices across the board (holding income constant) will result in a 30% decline in dietary iron intakes (Bouis, 2008). One way of improving household food and nutrition security, particularly amongst the rural poor, could be to promote home production of foods rich in those nutrients shown to be deficient in the diet of this particular target group (whilst at the same time meeting the requirements of sustainable production and consumption).

In a country like South Africa, water may be a limiting factor for home production. Water productivity (yield relative to water input) of crops / food products is influenced by many factors (Ali & Taluker, 2008), some of which are site- and production method specific and others are crop-specific (Gerbens-Leenes & Nonhebel, 2004). Numerous initiatives are currently underway in rural areas of South Africa to increase productive water use at household / communal / subsistance level (for examples see Backeberg and Sanewe, 2010; Backeberg, 2009; Khosa, 2003; Kundhlande et al., 2004; Stimie et al., 2010; Van Averbeke, 2008), but the idea to linking this to known nutrition problems is in its infancy, particularly in South Africa.

If the aim of agricultural interventions is to purposefully address specific nutritional problems through water-efficient home production of foods, then knowledge of the "nutritional water productivity" (nutrient yield/m^3 of water) of such foods (ideally in the relevant geographical sites produced under "typical" conditions) would be essential for credible nutritional and agricultural promotion and extension work.

1.1.2 Practical context

The following, purposefully extracted from the terms of reference of this project, show that the Water Research Commission has responded to the above theoretical rationale by soliciting a scoping study as a basis for locally relevant follow-up research and action.

"*In the biannual 'Overview of the World Food Situation' by the International Food Policy Research Institute at the end of 2007, it was stated that renewed attention should be given to agriculture, food, nutrition and health in adjusting research agendas. Strategies should be directed at poor members of society. With increasing risks caused by climate change, more investments should be made in agriculture to improve productivity. This includes investment in agricultural science and technology to facilitate a production response to rising food prices.*

In South Africa, the rural landscape is typified by high levels of poverty with approximately 70% of the country's poor residing in these areas and a significant (approximately 35%) proportion of the total population experiencing food insecurity. One of the main food security challenges facing the country is the need to increase the ability of vulnerable groups to meet their minimum daily requirements for adequate nutrition. At a conference on Nutrition and Food for Special Dietary Uses at the beginning of November 2008 in Cape Town, the former Minister of Health, Barbara Hogan stated that 'food insecurity and high rates of malnutrition, coupled with high food prices, remain the biggest threat to nutrition in Africa'. More research is thus needed in support of programmes that will improve health through balanced nutrition and the availability of food at reasonable prices. It is therefore important to know what food crops are currently available and also what alternative food crops can be considered for addressing nutritional imbalances. Among the strategies available to address malnutrition, supplements are options over the short-term; fortification over the medium-term; and better eating behaviour as part of the so-called food-based approach over the long-term. Information is available on what people should be eating on nutrient level, but little is known about what people are actually eating. In addition, very little local knowledge *is available on nutritional water productivity (i.e. nutrition per volume water expressed as nutritional units (kJ of energy; grams of protein; RE for vitamin A; mg of iron or zinc) per m^3). Both water and fertilizer management will determine the productivity of water and quality of crop food products.*

It is widely recognized that many residents living in rural areas have access to land and water resources for productive use. Furthermore the high unemployment rates, generally ranging from 30 to 40%, suggest the availability of labour to practice agriculture. Yet indications are that food produced at household level makes an insignificant contribution to the diet of rural households. This contradiction between rural poverty, food insecurity, inadequate nutrition and under- utilization of natural resources raises a number of fundamental research questions: Why are hungry and poor people not producing sufficient food; why are these particular groups of people consuming identified foods; what explains the current choice pattern (with reference to access, availability, affordability, preference issues) and what are the constraints which prevent certain foods being included in the regular food intake?" (Water Research Commission, 2011:64).

In conclusion: Food-based eradication of malnutrition on the public health level can only be effective if addressed with multiple interventions and across disciplinary boundaries (Allen & Gillespie, 2001; Ismail et al., 2003). The promotion of home-production of specific foods among the rural poor of South Africa should be based on scientific evidence, taking not only current best practice in agriculture and human nutrition into account, but also the socio-cultural context within which the interventions are to take place. This is one of the prerequisites for translating the existing political commitment and call for action into an increased readiness of the country to accelerate nutrition actions. Before embarking on empirical research in such a new field of inquiry, existing knowledge, which in all likelihood is fragmented, should first be explored. As will be evident from the following section, this was the aim of the WRC when soliciting this desktop study.

Figure 1.1 is a diagram summarising the context of the present study.

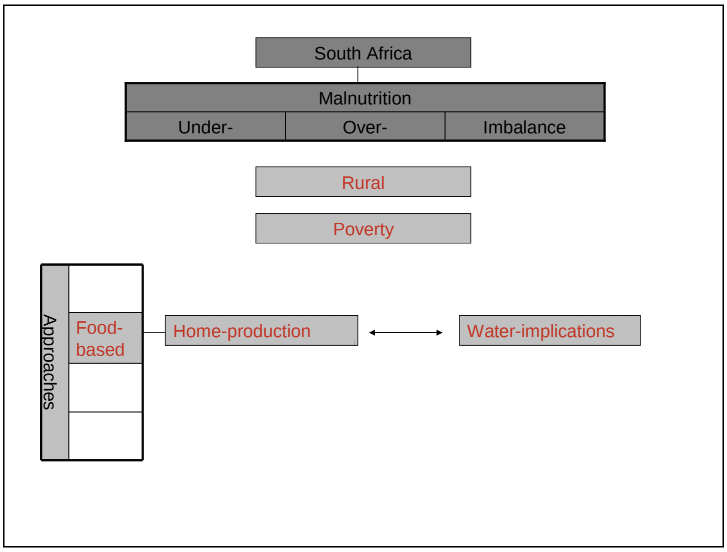

Figure 1.1: A contextual framework of the present study

1.2 TERMS OF REFERENCE, OBJECTIVES AND DELIVERABLES

This project falls in the key strategic area "*Water utilisation in agriculture*", the thrust "*Water utilisation for food and fibre production*" and the programme "*Water-efficient production methods in relation to soils, crops and technology in rain-fed and irrigated agriculture*" of the Water Research Commission.

The terms of reference for this solicited project contained the following aims and objectives:

The general aim of the project was to determine nutritionally important foods for the diet of rural households in South Africa with specific reference to the poor; and to describe the nutrient content and water use of related unprocessed crop and animal food products using existing knowledge.

In order to achieve the above general aim, the following objectives were set:

- To determine the contemporary food basket (food intake) across seasons of poor households in rural areas
- To assess the sources of components in the food basket (food intake) across seasons, for example home produced and / or purchased foods
- To characterise nutritional gaps in the food basket (food intake), identify the key nutrients and recommend foods and / or crop / animal products for household food and nutrition security
- To identify reasons for the contemporary food basket (food intake) of households at different poverty levels in rural areas
- To specify the water use of selected nutritionally important unprocessed crop and animal food products for human consumption
- To specify the nutrient content of the selected unprocessed and animal food products for human consumption
- To estimate benchmarks of nutritional water productivity (e.g. for protein g/m^3) for key nutrients of selected crop and animal food products
- To formulate draft terms of reference for a follow-up research project to address knowledge gaps in relation to nutritional water productivity in rural poor South Africa.

The deliverables associated with the aim and objectives are given in the Table 1.1:

Table 1.1 Deliverables of project K5//1954/4

Deliverable	Deliverable Title	Description
1	Report: Contemporary food basket	Report on the contemporary food basket of poor households in rural areas for example home produces and/or purchased food across seasons
2	Report: Sources of Foods	Report on the sources of components in the food basket of poor households in rural areas
3	Report: Nutritional gaps	Report on nutritional gaps in the food basket and identification of nutrients, food and/or crops/animal products for optimal nutrition and household food security
4	Report: Reasons for food intake	Report on reasons for the contemporary food intake of households across seasons in rural areas.
5	Progress report	Report on progress made in the first year of the project including capacity building.
6	Report: Nutrient content of selected food items	Report on nutrient content of the selected unprocessed crop and animal food products for human consumption.

Deliverable	Deliverable Title	Description
7	Report: Water use of selected food items	Report on water use of selected nutritionally important unprocessed crop and animal food products for human consumption.
8	Report: Nutritional water productivity of selected foods	Report on benchmarks of nutritional water productivity for key nutrients of selected crop and animal food products.
9	Knowledge dissemination	Scientific and / or popular article.
10	Final report	Final report on current understanding, knowledge gaps, spatial presentation and draft terms of reference for follow-up research to address knowledge gaps in relation to nutritional water productivity in rural poor SA.

Figure 1.2 is an overview of the project, showing the relation between the research questions (linked to the objectives) deliverables and the chapters of this report.

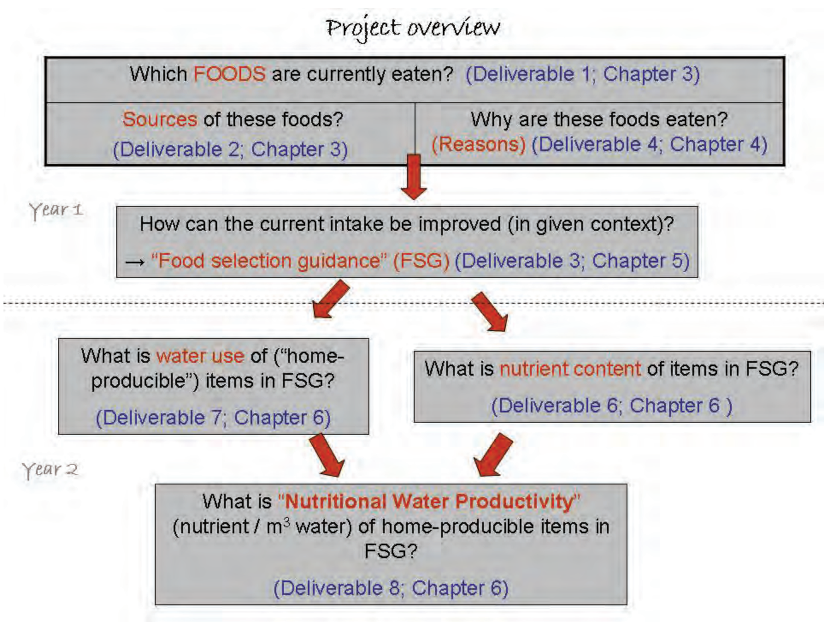

Figure 1.2 Relation between the research questions, deliverables and chapters of the report

1.3 OVERVIEW OF STRUCTURE OF REPORT

A meaningful point of departure when embarking on a new field of research is a *scoping study*, defined as the process of summarising a range of evidence in order to convey the breadth and depth of a field. It is an exploratory project that systematically maps the literature available on a topic, in order to identify the key concepts, existing evidence and gaps in existing research (Levac et al., 2010). Against the backdrop of this definition, the structure for this report is as follows:

In *Chapter 2* the key concepts in the field are identified, conceptualised, contextualised and/or theoretically or operationally defined, bringing together the voices of the three disciplines involved in this study, namely social anthropology, human nutrition and agronomy.

Chapter 3 comes from a human nutrition perspective. It concisely reviews existing knowledge of food intake and sources of food focussing on work done since 1994 among the rural poor of South Africa.

In *Chapter 4* the reasons for food intake in the specified target group are discussed in depth. Social anthropology guides the discussion which leads to the presentation of an ecological framework of the themes and factors influencing food intake.

Using the knowledge generated in preceding chapters, inclusive food selection guidance for follow-up studies that aim to address the nutrition problems of the rural poor of South Africa through home-production is presented in *Chapter 5.* The nutrient composition of these selected foods concludes the chapter.

Chapter 6 puts into context the water use efficiencies and nutritional water productivities mainly of the foods contained in the food selection guidance.

All the core chapters and, in particular, the concluding chapter aim to guide future research. Hence the ultimate aim of the study was to provide direction for follow-up research enquiries. This, in turn, was also stimulated by the slogan (adapted from the FAO) of a previous WRC project (WRC K5//1579/4), namely

Fewer drops, more crops, most nutrition!

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CHAPTER 2

CONCEPTS AND DEFINITIONS

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2.1 INTRODUCTION

During the "*2020 Conference Leveraging Agriculture for Improved Nutrition and Health* "it was found that a key barrier to integration between agriculture, nutrition and health professionals was the lack of a common language with which to debate (Harris, 2011). Thus, in order to facilitate communication across disciplinary boundaries amongst the readership of this report, as well as to consolidate the research team's interpretations and use of concepts, this chapter clarifies some of the key terms of the report.

As stated in the introductory chapter, not only the understanding of terminology and definitions, but also the tone and writing style used in the social sciences (e.g. social anthropology), human nutrition and natural sciences (e.g. agronomy) differ considerably. In order to capture this as a reflection of a multidisciplinary project, the writing styles of the project collaborators were purposefully retained in this chapter.

In the first section ("conceptualisation of the study context") a detailed description of the core concepts "poor people" and "rural areas" is given. This is followed by study-specific delineations of health, food and nutrition concepts. Lastly agriculture-related terminology is defined.

2.2 CONCEPTUALISATION OF THE STUDY CONTEXT

Rural Areas and Poor People

Poor people residing in rural areas are the focus of investigation by many scientific disciplines around the world but particularly those interested in development and related concerns (e.g. poverty) in countries of the Global South. Consequently, and in spite of the heavy international influence of economists from the World Bank and other multilateral development organisations, multidisciplinarity has resulted in the concepts of poverty and rural having a wide range of meanings and subsequent indicators that are used in definitions. Often use of these concepts is done in a confusing and ill-informed fashion (Noble et al., 2004 cited in Meth, 2006).

In South Africa there is a stark racial and gender differentiation to poverty along with a strong spatial dimension in the occurrence of poverty. Using official Statistics South Africa datasets, May (2000: 21, 22) reports that 49% of South Africa's population are poor with around 72% of the country's poor residing in rural areas and that 71% of all rural residents are poor (see also Goldman & Reynolds, 2007 who provide similar figures using the Rural Development Framework of 1997). Statistics SA

(2003) reported that poverty in South Africa had declined to about 43%. Official statistics suggest a strong link between rural residence and poverty.

However, neither of the terms rural nor poverty has an officially or formally agreed upon and accepted definition in South Africa. Poverty is used in both broad and narrow senses, and is made more confusing when there is an absence of a rigorous distinction between the ways in which poverty is conceptualised, defined and measured (Goldman & Reynolds, 2007; SPII, 2007). Rural is often used dichotomously, in contrast to urban characteristics of service delivery, population density and settlement patterns, which pose a number of problems given South Africa's former homeland policies and legislation. The remainder of this section discusses the terms poverty and rural areas, and in light of the complexities involved, explains how we used these terms in the current study.

Poverty and the Poor

The term poverty is mostly used to capture a range of meanings that relate to a lack of something that is necessary for survival. Often this is interpreted as the material lack of resources that are deemed necessary for survival. A narrow interpretation of poverty refers to a lack of income to purchase the resources required for survival (*income poverty*) (Aliber, 2002). Poverty can also refer to a lack of access to food (*food poverty*) which can result from the lack of income (*income poverty*) to purchase or access food. However, food poverty is determined by multiple factors such access, availability, quality and services to store and utilise food optimally (not simply income) and forms the link between poverty and food and nutrition insecurity. While income poverty and food and nutrition insecurity are synonymous, they are not always strongly correlated.

A broader interpretation takes into account the multidimensional nature of poverty and includes the lack of access to infrastructure and services such as potable water, sanitation, electricity, roads, housing, health and education. This broader interpretation is known as the *quality of life* aspect of poverty and is not necessarily related to personal income (Aliber, 2002: 4). Since the late 1990s more nuanced understandings of the experiential aspects of poverty in South Africa have resulted in the awareness that the lack of access to resources and integration within social power relations (SPII, 2007: 10), which result in social isolation and possibly family fragmentation, along with feelings of vulnerability, powerlessness, hopelessness and blatant disrespect from officials, prevent people from participating completely as full citizens in the broader society (Aliber, 2002: 4). Access to and the quality of infrastructure and services are typically lower in rural areas in contrast to urban areas.

Inequality is another important aspect of poverty, having a broad sociological and narrower economic quantitative meaning. In the sociological sense inequality is linked to power relationships and exists if group membership is dependent on different power relationships. It is evident in societies where social hierarchies are firmly institutionalised. For example where class and race are intimately linked as is the case in South Africa. In the economic sense, inequality refers to an imbalance in the distribution of resources in a particular population. Income is often one of these resources and the Gini coefficient is used to measure inequality. The Gini coefficient can range from 0 (no inequality) to 1 (complete inequality). South Africa has a high Gini Coefficient, currently in the region of about 0.7 (NPC, 2010). In South Africa the Living Standards Measure (LSM) is also used to measure inequalities. It computes an average monthly income based on 29 variables. Policies that are used to reduce inequality involve the redistribution of resources from wealthier groups in a society (or population) to the poorer groups.

If one is seeking to count the poor then it is necessary to distinguish the poor from the non-poor in some manner. This is sometimes achieved by using a poverty line which is a monetary measure based on monthly income or expenditure per adult equivalent with reference to the income or expenditure required to avoid poverty, however poverty is conceptualised. Expenditure is generally considered to be a more accurate and composite measure and can represent the contribution of income from informal sources.The use of income/expenditure is known as an indirect definition (SPII, 2007: 28). Poverty may also be defined by using a set of poverty indicators – access to type and quality of water, access to sanitation, dwelling type, access to electrification, energy type, etc. (May, 2000). These comprise a more direct definition of poverty. There are strengths and weaknesses in using both direct and indirect approaches (SPII, 2007: 30). In 2008/2009 StatsSA launched the Living Conditions Survey in an attempt to get a more direct definition and poverty profile of South African households. This used both direct and indirect approaches. So far only the results of the expenditure component have been made available (StatsSA, 2010).

The *poverty line* (also sometimes referred to as the poverty threshold) is a statistical representation of the total value of goods and services necessary for either a household or individual to survive – usually the minimum level of income deemed adequate in a given country or internationally. Once this value has been computed (often in money metric terms using income or expenditure) as a poverty line. Determining the poverty line is usually done by finding the total cost of all the essential resources that an average human adult consumes in one year., The resultant value is then, by means of quantitative survey data, used to analyse the distribution of resources within a country in order to illustrate how many people in a country fall above or below the poverty line. Often the tool used is a money metric poverty line that is represented as a single global amount of money, with no clear idea as to what basic needs should be included or excluded. The common *international poverty line* has in the past been roughly $1 a day. In 2008, the World Bank came out with a revised figure of $1.25 at 2005 purchasing-power parity (PPP). Essentially a poverty line is a narrow measure and provides a snapshot of the distribution of resources (typically income), but cannot inform us of the depth of poverty in broader terms or provide a nuanced analysis of the existing manifestations of poverty in a country. Furthermore, a poverty line can at best reflect that people who live above it ought to be enjoying a certain quality of life, but it cannot provide any guarantee of the actual well-being of these people. A poverty line is therefore a proxy of the goods that money could purchase but does not consider whether or not these goods are actually purchased or received. However, despite these weaknesses, the poverty line is one of the most commonly used measures of poverty worldwide. Even though there is no official poverty line in South Africa, Statistics South Africa uses two poverty lines at 2008 constant Rand. One is R524 and the other is R283 per person per month (NPC, 2011).

Within any group of people who are defined as poor, other sub-categories are invoked to distinguish the different experiences of poverty within such groups. For example, Roberts (2001) defines a household as ultra-poor if its monthly adult equivalent expenditure is less than half the poverty line.

Poverty Gap Index is an economic measure of the depth of poverty (P1) and the severity of poverty (P2 – the squared poverty gap index) and refers to the amount of resources required to bring all members of a population above a designated measure of poverty, i.e. move the entire population out of poverty (SPII, 2007). The transfer of the resources involved would need to occur annually in order for the poverty gap to remain closed. In South Africa the depth of poverty (P1) at a poverty line of R388 per month in constant 2008 Rand is based on how far below the poverty line the average income of an average poor person is. Using the same poverty line, the severity of poverty (P2) is based on the square of the gap between the poverty line and the incomes of the poor; therefore it gives greater weight to those who are most deeply in poverty (NPC, 2011).

Poverty is often discussed in absolute and relative terms. *Absolute poverty* is an attempt to reach an objective standard for identifying and measuring poverty. It usually refers to a fixed state of deprivation defined in relation to a supposedly objective, invariant and value free external definition of basic human needs around the world (SPII, 2007). Thus the standard of absolute poverty (e.g. the international poverty line) remains unchanged in a society over time irrespective of the needs of different groups. However, claims to be objective or scientific are questionable as any definition of human needs, and by extension poverty, are value-laden and based on prevailing political and ideological assumptions.

Relative poverty, in contrast to absolute poverty, classifies individuals or households as 'poor' by comparing them to others in the population under study, for example a particular country or society. Its relevance increases if there is a need to focus on inequality in society, as is the case in South Africa. Relative poverty also acknowledges that what it means to be poor will change both temporally and spatially. It is used in both narrow and broad terms. In a narrow sense it refers to the national distribution of income or expenditure (May, 1998) and in its broadest sense to full participation in society (Noble et al., 2004).

The study of poverty has become multidisciplinary as it has been realised that poverty is manifested in a number of ways, and is not purely economic in orientation as was largely assumed in the 1950s and 1960s.Although economic influences prevail in attempts to reach national and universal benchmarks, multidisciplinary studies have reinforced the need for broader and more nuanced understanding of poverty. Terms that have become prevalent in the literature on poverty include ideas of vulnerability with links to experiences of chronic and transitory poverty.

Vulnerability is a concept that is often used in relation to poor people and poverty. People are considered to be vulnerable when they are at a tipping point, whereby the slightest shock, from which they would normally be expected to recover with ease, causes them to experience a catastrophic situation from which it is not only extremely difficult to recover but also increases their experience of poverty and reduces their assets or access to assets required for recovery (Devereux, 2002; Ellis, 2003). Vulnerability is defined as the function of two properties in a system: *sensitivity* (the extent to which the system is impacted by a shock) and *resilience* (the ease and speed with which the system recovers) (SPII, 2007). People become vulnerable when their livelihood systems are very sensitive and not very resilient (Du Toit & Ziervogel, 2004). Chronic poverty and transitory poverty are linked to the concept of vulnerability.

Chronic poverty describes the experience of a state of poverty overtime and that those experiencing chronic poverty do so for extended periods or even most of their lifetime – it is a continuous state of affairs. Furthermore, it is likely that this experience is intergenerational in that the children of the poor are likely to find themselves and their children being poor during their lifetimes. South Africa experiences both chronic poverty (Du Toit, 2005) and chronic food insecurity (HSRC, 2007). Chronic food insecurity is long-term or persistent and is closely related to structural deficiencies in the local food system or economy, chronic poverty, lack of assets and low incomes which persistently curtail food availability and access over an extended period of time (DFID, 2004; FAO, 2005).

Transitory poverty refers to a state of poverty in which people are able to move out of after a relatively short period. Transitory poverty is usually sudden in onset, short-term or temporary and refers to relatively short periods of extreme scarcity of or access to income, food, water, shelter and other means of survival (Barrett & Sahn, 2001). Such situations can be brought about by climatic shocks, natural disasters, economic crises or conflict. Experiences of transitory poverty and related food insecurity may arise through smaller shocks at the household level (e.g. loss of income, forced migration and crop failure). The concepts of transitory and chronic poverty are important given their attention to the dynamics associated with escaping poverty or remaining poor (Hulme & Sheperd, 2003).

Social exclusion is another concept used with respect to poverty and poor people. It was initially referred to in European debates about why particular minority groups (single mothers, immigrants, the insane) were poorly integrated within the welfare systems of these countries. The current use of the term refers to the processes through which the poor are purposefully excluded or marginalised from mainstream economic, political and social life (SPII, 2007). The emphasis of social exclusion is on the importance of social processes and social relations, and how adverse power relations, discrimination and identity contribute to the marginalisation and impoverishment of people. A nuanced approach to social exclusion emphasises that poverty is related to the complex interaction of inclusion and exclusion. Inclusion can be adverse if it is done on unfavourable terms, such as the historical inclusion of black South Africans into the economy while simultaneously excluding them politically (ibid.; Du Toit, 2004).

The *poorest of the poor* is a term frequently used by various state departments in South Africa in attempts to identify beneficiaries of policy interventions. While there is no agreed upon definition of the term it is commonly used to refer to what are considered to be the most vulnerable groups within South Africa. These groups include poor children, poor old age pensioners, female headed households and rural residents. Its use can be confusing for at least two reasons. Firstly it assumes that these groups are homogeneous, having similar experiences, and thus require equal and similar assistance. Secondly, it can result in the misunderstanding that others outside these categories are less deserving. For example, a male headed household may also require assistance but is ignored as a result of the focus on female headed households.

Multiple understandings of the *causes of poverty* influence the formulation of policies and strategies aimed at poverty reduction and mitigation of its effects. There are generally three diverse views relating to the causes of poverty: residual; pathological; and structural. *Residual* causes of poverty attribute poverty as a consequence of being left out of the national and international economic growth and development process (Bernstein et al., 1992). Movement out of poverty is thus seen by supporters to be achievable by means of inclusion into these processes through the 'trickle down effect' where it is assumed that more people must simply be linked to markets or participate in employment. This understanding is prevalent in South African Government circles. Following from residual notions, *pathological* explanations tend to emphasise that people are responsible for their own poverty. Advocates of this understanding of the causes of poverty argue that a person's poverty is a result of their failure to get a job and that this is a result of their own lack of initiative or desire to work. Other reasons for not obtaining employment are excluded from such arguments. *Structural* causes of poverty argue that growth and development themselves contribute to the production of poverty and inequality. To address poverty the policies and programmes must actually change the structure of the nature of the prevailing social, political and economic forces (Alcock 2006). In an era of globalisation it is clear that unemployment in South Africa – often seen as a cause of income poverty – is influenced by changes in the global and national economies – particularly production and markets – and the historical trajectory of the political economy (SPII, 2007: 15).

From our discussion it is evident that poverty is conceptualised and defined in a variety of ways and with different emphases. These different definitions and associated measures focus attention on and quantify different aspects of the dimensions of poverty. Each definition is important as there is no single ideal definition that is capable of capturing the complexity and multidimensionality of poverty. Concepts and definitions of poverty have moved from a narrow focus on absolute resource based subsistence definitions to ones which are both relative and *multidimensional*, and which can also change over time (Lister, 2004). If only one poverty line or set of indicators was used to understand poverty and measure poverty then the important multidimensionality of poverty would be ignored.

Given the existence of the multiple meanings of poverty and what it denotes, we relied on the use of poverty as or part of a keyword in our selection of documentation to include in the study. In most instances poverty was not clearly defined. At best some authors may have used a very narrow poverty line to indicate the differing levels of poverty of their subjects/respondents. In most cases we relied on the use of the word poverty without any clear definition or indicator being attached to it. However, it was often linked to specific groups of people who are generally accepted to be poor in terms of income and access to services, such as farm workers, women and children in remote rural households.

Rural Areas

To overcome the lack of a formal and accepted definition, policy makers and researchers often rely upon identifying characteristics that assist in distinguishing rural and urban areas. The 1997 Rural Development Framework for South Africa (Government of South Africa, 1997: 1) defines rural areas as:

> … sparsely populated areas in which people farm or depend on natural resources [such as land, crops and livestock required for farming, as opposed to those required for mining], including the villages and small towns that are dispersed through these areas. In addition they include the large settlements in former homelands, created by the apartheid removals, which depend for their survival on migratory labour and remittances.

Although never adopted as an official definition many government departments appear to use this as a working definition, largely because it coincides strongly with the conditions that affected rural dwellers prior to 1994. Such a definition distinguishes rural areas from urban by emphasising the density of population and settlement patterns, the livelihoods and resources available, and the history of rural areas. Consequently, two primary types of rural areas appear to exist in terms of this definition: Commercial farming areas and the former homelands or traditional authority areas (Goldman & Reynolds, 2007). This is a confusing form of classification because the one category is based on an economic definition and the other on historical politico-legal definitions!

The *commercial farming* areas cover much of South Africa outside of the metropolitan areas and are characterised by large-scale commercial farming units interspersed with small towns, villages and in some districts small pockets of the former homelands. Goldman and Reynolds (2007) indicate that the rapid population increase in the small rural towns after 1994 is a consequence of the inward migration of former and transitory farmworkers and their families. This pattern of inward migration to these small rural towns has also been a consequence of the attraction of access to the housing provided by the Reconstruction and Development Programme (RDP). However, economic and employment prospects in these towns are few and have not increased in proportion to the population increase (ibid.).

The *former homelands* are a result of South Africa's legacy of *apartheid* (separate development) policies. As a result they are often displaced and overpopulated semi-urban settlements, which has undermined their historical and current economic base (Goldman & Reynolds, 2007). Here many households attempt to survive through a combination of seasonal and sometimes intermittent production on household food plots and communal land, remittances from urban migrants, state pensions, local piece-work and informal sector activities (see Aliber, 2005; Aliber & Hart, 2009; McAllister, 2001).

According to the 2001 Census of Statistics South Africa (StatsSA, 2003), 43% of South Africa's population lived in a rural area, which was defined as any area that was not classified as urban and followed the distinction between commercial farms and tribal areas (another term for the former homelands based on their imposed 'traditional' style of leadership) (StatsSA, 2004). Census 2001 suggested that the provinces with the highest rural populations were respectively Limpopo (87%), Eastern Cape (61%), North-West and Mpumalanga (58%) and KwaZulu-Natal (54%). StatsSA (2004) has attempted to consider settlement classification as a means of addressing the problem by identifying four key types of settlement in South Africa:

- Formal urban areas;
- Informal urban areas;
- Commercial farms; and
- Tribal or traditional authority areas of the former homelands and rural informal settlements.

However, rather than removing politico-legal determinants to spatial settlement it has been reinforced as the classification of rural areas is based on the RDF of 1997.

As Goldman and Reynolds (2007) point out, the absence of an acceptable definition of urban and rural in South Africa remains problematic. While the shift by researchers this century to focus on metropolitan areas and district municipalities is an attempt to overcome the barriers resulting from a lack of an acceptable and agreeable definition of rural and clearly distinguishing it from urban, it has proved obstructive. In practice what occurs is that most municipalities, including large metropolitan areas such as eThekwini (Greater Durban) and secondary cities, for example Mangaung (in Bloemfontein), comprise of significant rural areas, although the share of the population in these areas may be small (ibid.). The dividing lines between city, peri-urban, large town, small town, farm and deep rural areas are very blurred. This lack of clarity tends to disadvantage the people in some of South Africa's most impoverished areas.

The introduction of the Integrated Sustainable Rural Development Programme (ISRDP) in 2001 is a good example of the confusion that occurs even in so called 'accepted rural areas' when the district and local municipalities are used as proxies for rural. The ISRDP identified 13 rural nodes (11 district municipalities and 2 local municipalities) across South Africa. However these nodes included local municipalities with large towns, such as the Chris Hani District Municipality node in the Eastern Cape, which combines farming districts of the former Cape Provincial Administration, parts of the former homelands of the Ciskei and Transkei and the large town of Queenstown. The ISRDP nodes also include local municipalities that are considered to be 'deep' or 'very rural' in the sense that they are located in very remote areas, often with little infrastructure and services – both public and private. As Gopaul (2006: 20, 21) argues these municipalities are further characterised by low levels of employment, poor housing, low wages and a low state of living. ISRDP examples include the Gasegonyana, Gamagara and Moshaweng local municipalities in the Kgalagadi ISRDP node in the North West and Northern Cape, and Ugu in the Eastern Cape. South Africa now has 22 so called Rural District Municipalities!

Drawing from official sources at the time (Department and Local Government and The Presidency), the 2006 *State of the Cities Report* presents a typology of settlements akin to that of the 1997 RDF and that proposed by StatsSA (2004). However, this is more detailed and defines settlement types in terms of settlement characteristics (size, population density, assumed core livelihoods), size and potential of existing economic base, and their institutional context. However, they attempt to avoid using rural and treat it as some 'residual' – everything is seen as being non-urban!

Bearing in mind the various complexities and contradictions inherent in defining rural areas and populations living in various municipal areas, all with differing degrees of infrastructure and service access, the Rural Doctors Association of South Africa (RudASA) attempted a definition of rural and urban areas during the process of formulating a *Rural Health Strategy for South Africa* (RudASA, 2006). RudASA suggests the following four categories, of which residents in the first two areas would be classified as 'urban' and those in the latter two types as 'rural' (2006: 5):

> *Metropolitan area:* Metropolitan municipality.
> *Other urban area:* Local municipality that includes a city or large town and has mostly tarred roads, mostly piped water and flush sanitation, and a wide choice of services.
> *Close rural area:* Local municipality that has small towns, > 50% of people live within 5 km of a tarred road, most have piped water but a limited choice of services within that local municipality
> *Deep rural area:* Local municipality that has small towns and/or old "resettlement areas", > 50% of people live more than 5km from a tarred road, > 25% of people use water from streams, rivers, dams or rainwater tanks and people have a very limited choice of services within that municipality.

The report argues that it would be a fairly simple task to classify most municipalities into one of these four categories. In certain instances it becomes important to distinguish within the broad categories of urban and rural, so as to address specific gaps, needs and service requirements (specifically health requirements and services in rural areas in this example, such as sanitation and water which are often used as proxies for poverty). Because of the likelihood of changes in a municipality's status overtime, as services and infrastructure improve and migration patterns change, so municipal areas could be reclassified every ten years or so (RudASA, 2006). However, the heterogeneity within local municipal areas and across district municipalities cannot be overlooked, therefore it is perhaps more realistic to consider this type of classification at the village and ward level.

In conclusion, the ability to define an area as rural or urban remains contested and therefore problematic but the examples above provide some general characteristics that are important in demarcating rural areas. These include distances from metropolitan areas and other large towns, population density, extent of service delivery, the type, quantity and quality of livelihoods, resources and infrastructure, and importantly in South Africa their history, which involved the influence of politico-legal policies in shaping spatial localities.

As with the inclusion of studies on poverty, we relied on the use of rural as a keyword and also the geographic location of such studies, e.g. on commercial farms or in the former homeland areas where agricultural production of harvesting from the wild were considered important sources of food but not necessarily the main or only source of food.

2.3 HEALTH, FOOD AND NUTRITION-RELATED TERMINOLOGY

Biologically speaking, human nutrition refers to the ingestion (i.e. intake or consumption), digestion, assimilation (i.e. metabolism or utilisation) and excretion of foods (including drinks or beverages) and the nutrient and non-nutrient components thereof. In this report the focus is on the *intake* of *foods* only. Regarding intake, the focus is on what is eaten on individual level (as opposed to household or national level), where it comes from and why it is eaten – primarily from a behavioural perspective.

In the following table the emphasis is on the operational definitions as applied in this study. Most concepts are universally used in the field of human nutrition, yet are defined there to delineate them and avoid confusion in a multidisciplinary context. Core terminology is elaborated upon in related chapters of the report.

Table 2.1 Human nutrition-related terminology

TERM	OPERATIONAL DEFINITION FOR THIS STUDY
Sources of food	The origin of the foods available to or consumed by households, i.e. from where the households obtain the food they eat. In some of the studies consulted this was called *procurement* or *acquisition*.
Food intake	See chapter 3 for a theoretical delineation and the application thereof in this study.
Evaluation of food intake (Dietary evaluation)	The *interpretation / judging* of the diet quality of the food intake data using appropriate dietary standards as yardstick.
Diet(ary) quality	The *nutritional (dietary) adequacy* (as opposed to aspects such as organoleptic properties, microbiological safety, etc. of food, or nutritional intake from non-conventional foods or supplements) based on total food intake of individuals or groups (ideally over time).
Dietary standards	Tools used to evaluate dietary intake; this includes nutrient-based standards, diet quality scores and food-based dietary guidelines; mostly these standards are quantitative (to find confidence of adequacy), but some are qualitative (to find probability of adequacy).
Nutrient-based standards	Nutrient (as opposed to food, food component or dietary) intake values or references, e.g. Dietary Reference Intakes (DRI)
Diet(ary) quality scores	Diet indices or composite dietary tools (often numerical) that measure (aspects of or total) food intake; usually predefined; mostly, but not always food- or dietary pattern-based, e.g. Dietary diversity Score (DDS).
Nutritional gaps	The difference between a current intake (in terms of nutrients or foods) and a desirable dietary standard or other measure of diet(ary) quality.
Contemporary intake	*Current* intake; in this report this referred to studies reported in 1994 or later. Studies based on (out)dated data (i.e. where this was explicitly stated) were excluded.
Seasons	*Natural* (as opposed to social, e.g. festive) cycles; usually this had to be inferred from the timing of data collection.
Nutrition security	Internationally (specifically the Committee on World Food Security) there is not yet consensus on the terms "Food Security", "Food Security and Nutrition", "Food and Nutrition Security" and "Nutrition Security". Currently (August 2012) an online consultation termed "*Coming to terms with terminology*" is held in relation to this. In this report nutrition security is determined by the availability of health services, a healthy environment (to ensure effective biological utilisation of foods consumed), the quality of

TERM	OPERATIONAL DEFINITION FOR THIS STUDY
	care an individual receives, in addition to household food security (UNICEF, 1990).
Energy	The caloric (or kilojoule) intake from the ingestion of foods by humans.
Nutrient	A component of food that is essential for human nutrition.
Macronutrients	Energy-yielding nutrients in human nutrition, namely carbohydrate, fat and protein. (Alcohol – even though energy-yielding – was not included in this study).
Micronutrients	Vitamins and minerals.
Non-nutrient food components	Part(s) of food that that are non-essential (i.e. the absence thereof does not lead to a nutritional deficiency), even though these may be health promoting (e.g. phytochemicals), harmful or with no known health effects.
Nutrient density	Nutrient density refers to the amounts of key nutrients contained per 100 kcal of a food (Drewnowski, 2009). Nutrient dense foods and beverages provide vitamins, minerals and other substances that may have positive health effects, with relatively few calories/kilojoules (energy). Examples include vegetables, fruits, whole grains, low-fat dairy, lean meats and poultry (when prepared without solid fats or added sugars).
Food composition	The chemical “make-up” of foods; for this study specifically the nutritional components (energy, macro- and selected micronutrients) in foods, preferably expressed per (or converted to) 100 g raw, edible portion, in contrast to *dry* mass (in order to calculate nutritional water productivity)
Food composition database	A paper-based or electronic tabulation representing an approximation of the real nutrient (and non-nutrient) content of food (based on Joyanes & Lema, 2006). For the purpose of this report the “Condensed Food Composition Tables for South Africa” of 2010 compiled by the Nutritional Intervention Research Unit of the Medical Research Council (MRC) of South Africa based on information from the South African Food Data System (SAFOODS) (Wolmarans et al., 2010), is considered the reference database.
Food selection guidance	In this project food selection guidance is the term used to describe the project-specific foods suggested for follow-up investigation by agronomists. It is an attempt to encapsulate the criteria developed in this study. The term does NOT imply “nutritionally important foods”, or a guideline or “nutritional recommendation for addressing malnutrition”.

2.4 AGRICULTURE-RELATED TERMINOLOGY

According to the Oxford dictionary **agriculture** refers to the science or practice of cultivating the soil and rearing animals. **Agronomy**, more specifically, is the science and technology of producing and using plants for food, fuel, feed, fibre and reclamation. Agronomy encompasses work in the areas of plant genetics, plant physiology, meteorology and soil science.

Water is central to agricultural production, whether this is so called “dry-land” or “rain-fed” agriculture, production under supplementary or full irrigation, or animal production – without water, no production is possible. This project looks at the efficiency with which this water is used, specifically the water efficiency of important nutrient production.

Against this backdrop, some terms specifically relevant to the current project are defined:

Table 2.2 Agriculture-related terminology

TERM	DEFINITION OR DESCRIPTION FROM LITERATURE
Evapo-transpiration (ET)	A combination of two processes which occur simultaneously. These are evaporation and transpiration. Evaporation refers to the physical process of water vapourisation into the gaseous phase directly from the soil surface, whereas transpiration is a biophysical process where water is transported from the plant root zone through its cells and stomata into the atmosphere (Allen et al., 1988; Wegerich et al., 2010).
Green water	The portion of precipitation that replenishes soil water and is consumptively used by crops through ET (Stirzaker, 2010).
Blue water	Water in fresh lakes, rivers, dams, and aquifers which can be abstracted for various uses such as irrigation, domestic use and livestock watering, industrial and urban use; and to support aquatic ecosystems (Hoekstra et al., 2009; Kauffman, 2008).
Grey water	Rodda et al. (2010), have defined grey water as effluent from baths, showers, kitchen, laundry, and wash basins. However, in agriculture, some consider waters contaminated with agro-chemicals such as fertilizers, pesticides and fungicides which are leached or that reach surface water bodies through runoff to be grey waters (Hoekstra et al., 2011).
Black water	Wastewater that has been contaminated with sewage. It needs treatment to be reused as it contains potential health hazards, and has a high biochemical oxygen demand, indicating a low quality. Currently this water is not used directly in South Africa to irrigate crops, but is recycled through water treatment plants and released back to water bodies (Stirzaker, 2010; Wegerich et al., 2010).
Crop water requirements	Amount of water that is needed by a crop to satisfy ET demand by the atmosphere throughout the growing period of the crop, in a specific location with its own climatic conditions (Allen et al., 1988).
Crop water use	Water actually used by the crop. Crop water use is influenced by available water in the soil, crop species, and growth stage (Kaisi & Broner, 2009).
Field capacity (FC)	Amount of water that is held in soil after it has been fully wetted (saturated) and allowed to drain freely for a few days (Kort, 2010). It corresponds to a soil water potential (Ψ_m) of about -10 J/kg.
Permanent wilting point (PWP)	Soil water content at which indicator plants growing in the soil will wilt and fail to recover even if placed in a saturated (100% relative humidity) atmosphere for 12 hours. It is estimated at -1.5 MPa metric potential (Dekker, 2003).
Water holding capacity	The amount of water that a soil can store and is available for plant water use. It is held between field capacity and permanent wilting point (USDA, 1998).
Water use efficiency (WUE)	The ratio of crop yield (usually economic yield) to water used to produce the yield (Bluemling et al., 2007).
Crop water	CWP is used synonymously with WUE in this report, but this is not strictly

TERM	DEFINITION OR DESCRIPTION FROM LITERATURE
productivity (CWP)	speaking correct. Some argue that the concept of CWP is much more comprehensive and relates product income to water use per farm or irrigation scheme. With this definition, a range of variables that influence quantity and quality of crop yield and income have to be quantified, including water (Backeberg, 2012 personal communication).
Nutritional water productivity	Ratio between nutritional content of a product per unit water used (Renault & Wallender, 2000).
Virtual water	Water "embedded" in a product, or water consumed during the production process and often used when a product is imported or exported (Renault, 2002; Wegerich et al., 2010).
Water foot print	The volume of fresh water that is utilized to produce a product and is measured over the whole supply chain. It is a benchmark for quantitative water use and one can relate single units of consumer products such as food; i.e. the water foot print depicts total water resources needed to produce and supply a product (Hoekstra et al., 2009; Wegerich et al., 2010).
C3 photosynthesis	A mode of photosynthesis where CO_2 is first incorporated into a 3-carbon compound and the RUBISCO enzyme plays a major role in the uptake of CO_2. C3 plants have lower water use efficiency than C4 plants because they keep their internal CO_2concentration relatively high and therefore stomata need to remain wide open and more water is lost through the process of transpiration. Examples are rice and barley.
C4 photosynthesis	A mode of photosynthesis where CO_2 is first incorporated into a 4-carbon compound and the PEP carboxylase enzyme plays a major role in the uptake of CO_2. C4 plants have a high water use efficiency because internal CO_2 concentrations are kept low so that they do not need to keep their stomata widely open at all times, thus losing less water compared to C3 plants. Examples are tropical grasses like maize, sorghum, sugarcane, millet and teff.
Harvest index (HI)	Ratio of harvestable mass to total above ground crop mass. The HI for cereals is approximately 0.5, whilst for leafy vegetables it can be around 0.8 (Kawano, 1990).
Livestock water productivity	Ratio of net beneficial livestock related products and services to the water depleted in producing them. Beneficial outputs are meat, milk, hides, manure, wealth, and savings (Peden et al., 2007; Descheemaeker et al., 2009).
Vapour pressure deficit	Difference between the saturation vapour pressure and the vapour pressure of the ambient air (Norman & Campbell, 1998).

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CHAPTER 3

FOOD INTAKE AND SOURCES OF FOOD OF POOR HOUSEHOLDS IN RURAL AREAS OF SOUTH AFRICA

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3.1 INTRODUCTION

As indicated in Chapter 1, malnutrition (referring to undernutrition and overnutrition) is a public health problem in South Africa, with poor households from rural areas being particularly vulnerable.

Economic crises and increases in food prices affect global nutrition (Webb, 2010). On national and household level similar associations have been reported, with household food insecurity as a result of poverty being one of the underlying causes for maternal and child malnutrition and death. South Africa has not escaped the global financial crises of 2007-2009. The National Agricultural Marketing Council (NAMC) reported in the Food Price Monitor that rural citizens were disproportionately affected: In April 2010 consumers in rural areas paid R17.78 more for the same food basket than consumers in urban areas. Temple et al. (2011) were able to show that in rural South Africa healthier food choices are considerably more expensive than commonly consumed food, making a healthy diet unaffordable for a very large segment of the population.

The above context, international findings that diet costs are associated with diet quality (Bernstein et al., 2010; Bouis, 2008; Drewnowski, 2010), the fact that the poor spend a larger percentage of their income on food (Martins, 2005), the bottlenecks in nutrition service delivery experienced in South Africa (Department of Health, 2009) and many other converging forces, lead to the conclusion that the rural poor can be expected to be particularly and increasingly at nutritional risk.

Access and availability are amongst the factors often linked to food intake and food and nutrition security of households and individuals, particularly in poor rural communities. Knowledge of the origin (i.e. the sources) of the foods that are currently being consumed by this group is therefore essential in the process of identifying appropriate interventions aimed at promoting the foods-based approach for addressing malnutrition in this vulnerable group of South Africans. The aim for this desktop study was to determine food intake and sources of food of poor households in rural South Africa.

3.2 METHODS FOR IDENTIFICATION OF STUDIES AND DATA EXTRACTION

For the identification of relevant literature electronic searches were conducted, supplemented by information provided by professional networks, hand searches, own collections and reference lists.

In Table 3.1 a summary of the platforms and databases used for the electronic searches is given. The searches were limited to English language in the publication years 1994 to 2010 (the search was conducted in April 2010) using the following keywords: (indigenous OR tradition* OR <u>rural</u>) AND (<u>food</u>* OR nutrition* OR diet* OR food basket) AND <u>South* Africa</u>. The underlined words were considered core.

Table 3.1: Platforms and databases searched

Platforms	Databases
OVID	Medline
Dialog	Biosis (Biological Abstracts) Agris International Foodline Science
EBSCO	Cinahl Africa-wide Information Eric
CSA (Cambridge Scientific Abstracts)	Agricola PsychInfo Social Services Abstracts
CAB Direct	Cab Abstracts (includes Global Health)
IFIS	Food Science and Technology Abstracts (FSTA)
WEB OF KNOWLEDGE	Science Citation Index

The sources identified were screened for meeting the requirements of this study.

In order to aid systematic extraction and appraisal of information, a flexible template for summarising the studies was created (see Table 3.2). The data is reported per province and for South Africa as a whole.

Table 3.2: Template for data extraction

Parameter	Justification
Research location	To provide information on the geographic area in South Africa so as to identify rural settings
Study sample / population	To provide information on the study population, sample size, stage in the life cycle, state of health; and socio-economics (so as identify poverty)
Study design / study purpose	To provide information on the design of the study and the aims / objectives so as to put findings in appropriate context
Study timing / season	To provide information on seasonality of food intake and create the option to plot findings along an agricultural calendar
Dietary assessment methodology	To provide information on dietary assessment methods and techniques as these relate to research question (aim), the study sample and context
Data on food intake	To provide information beyond nutrient intake and nutritional status, including types of food, foods most frequently consumed, foods consumed by the majority of the sample, food choices and preferences
Portion sizes	To provide information on quantities consumed
Sources for foods	To provide information on procurement strategies (future deliverable)
Reasons for food choices	To provide information on why people choose or eat the foods that they do (future deliverable)
Data on nutritional status	To provide information on anthropometry, biochemical indicators, clinical data and other psycho-social indicators which would affect the nutritional status
Micronutrient status	To provide information on the micronutrient intake and micronutrient status of the study population as determined by biochemical analysis

3.3. FOOD INTAKE IN THE PROVINCES AND NATIONALLY

3.3.1 Eastern Cape

3.3.1.1 OR Tambo and Alfred Nzo districts

Smuts and co-workers (2008) did a cross-sectional survey in 2003 that included 1794 randomly selected households. Table 3.3 shows the sources where households obtained their food from during the month prior to the survey, as well as the percentage of households who had a home garden and/or livestock. The majority of households obtained their food from shops. Although 77% of the households reportedly had a home garden (mostly for home consumption), only 26% obtained food from the garden the month prior to the survey, probably reflecting that the gardens do not provide food throughout the year. Although many households owned livestock, it was not a major source of food for household consumption.

Qualitative dietary data were collected for 2 to 5 year old children in the household, using a set of unquantified food frequency questions that focused on foods of animal sources, yellow/orange-fleshed vegetables and fruit and dark green leafy vegetables. Frequency of consumption of these foods was low, as is shown in Table 3.4. Sources of yellow/orange-fleshed fruit and vegetables and dark-green leafy vegetables for those children who consumed the specific food are also shown in Table 3.4 (please note that the values given in the Table are expressed as a percentage of those households who consumed the specific food). When consumed, carrot, pumpkin/butternut and spinach were grown in the home-garden by a significant number of households.

Table 3.3: Sources where households in OR Tambo and Alfred Nzo districts obtained their food from, using the month prior to the survey as guide, and ownership of a home garden and/or livestock

	OR Tambo (n=905) %	Alfred Nzo (n=889) %	All (n=1794) %
Source of food for the past month			
Bought/shops	76	79	78
Own home garden	32	19	26
Borrowed	10	10	8
Begged	9	10	9
Gifts	4	8	6
Communal garden	2	2	2
Own live stock	2	<1	1
Payment in kind	<1	1	<1
Food aid/welfare/NGO	<1	0	<1
Household has livestock	66	53	60
Household has a home garden	81	73	77
Main function of home garden [a]			
Daily food needs	88	90	89
Income	3	1	2
Daily food needs and income	7	8	8
Other	1	1	1

[a] expressed as a percentage of those households who had a vegetable garden; n for garden-owners not given

Source: Smuts et al., 2008

Table 3.4: Usual dietary intake of foods of animal origin, yellow/orange-fleshed vegetables and fruit and dark-green leafy vegetables for 2 to 5 year old children from two districts in the Eastern Cape; and sources of these foods

		OR Tambo (n=371) %	Alfred Nzo (n=493) %	All (n=864) %
Eggs	At least four days per week	18	33	27
	Approximately once per week	20	20	20
Meat	At least four days per week	4	12	8
	Approximately once per week	16	23	20
Chicken	At least four days per week	4	16	10
	Approximately once per week	17	26	22
Fish	At least four days per week	6	5	5
	Approximately once per week	9	11	10
Milk	At least four days per week	16	28	23
	Approximately once per week	9	17	13
Carrots	At least four days per week	4	7	6
	Approximately once per week	9	7	8
Pumpkin / butternut	At least four days per week	23	17	20
	Approximately once per week	21	19	20
Spinach	At least four days per week	21	18	19
	Approximately once per week	19	18	19
Imifino	At least four days per week	34	32	33
	Approximately once per week	17	20	19
Mango	At least four days per week	2	0	1
	Approximately once per week	3	1	1
Paw-paw	At least four days per week	2	1	1
	Approximately once per week	3	1	2
Sources, expressed as a percentage of children who consumed the food				
Carrots	*n*	*131*	*131*	*262*
	Shops	68	58	63
	Home garden	23	40	31
	Community garden	9	2	1
Pumpkin / butternut	*n*	*294*	*287*	*581*
	Shops	47	46	46
	Home garden	39	48	44
	Community garden	14	6	10
Spinach	*n*	*275*	*297*	*554*
	Shops	55	60	57
	Home garden	33	37	35
	Community garden	12	3	8
Mango	*n*	*79*	*103*	*182*
	Shops	100	98	99
	Home garden	0	2	1
Paw-paw	*n*	*80*	*98*	*178*
	Shops	91	98	95
	Home garden	9	2	5

Source: Smuts et al., 2008

A study in rural areas in the Central region of the Eastern Cape showed that the size of an average home garden was 0.5 ha. Vegetables planted in the home gardens were mostly cabbage, potatoes, onion, beans, peas, spinach, carrots and pumpkin, and maize was the main grain crop grown. Fruit trees in the home gardens included apple, peach and orange. The purpose of the home gardens was mostly for household consumption, while surplus of produce was sold. Home gardens increased food supply in the household, but did not satisfy the food requirements of the household or reduce household food expenditure (Mabusela 1999).

As part of a Master's study, McGarry (2008) determined the consumption of natural resources by rural children impacted by HIV/AIDS in Inland (n=372) and Coastal (n=378) areas of OR Tambo, Amatola and Alfred Nzo. The work suggests that wild foods may be a supplementary source of food for these children.

3.3.2 Free State

3.3.2.1 Bloemfontein district

Dannhauser and co-workers (1996) recorded foods consumed by children aged 6 months to 6 years from Rural Foundation (that offered educational programmes such as growing vegetable gardens, needlework and baking) and non-Rural Foundation farms using a quantified food frequency questionnaire. Foods consumed are listed in Table 3.5. Porridge made from maize meal, and usually consumed with milk, was the most frequently consumed food, followed by sugar and sweets, vegetables, margarine and meat. Vegetables were consumed twice a week, and fruit twice a month. Intake of vegetables and fruit seemed to vary according to availability and season. The size of the mentioned portion is, however, unclear. Sources of "free food" for households from Rural Foundation and non-Rural Foundation farms are shown in Table 3.6. Significantly more households on Rural Foundation farms had vegetables gardens (yet children from non-Rural Foundation farms consumed vegetables more frequently; Table 3.5).

Table 3.5: Foods consumed by 6 month to 6 year old children in Bloemfontein district

	Rural Foundation farms (n=159)		Non-Rural Foundation farms (n=164)	
	Median number of portions		Median number of portions	
Food item	Per day	Per month	Per day	Per month
Milk	2		2	
Maize porridge	6		6	
Tea (with milk)	1		1	
Meat		8		4
Fish		0		0
Chicken		4		4
Eggs		4		4
Brown bread		4		4
White bread		0		0
Fruit		2		2
Vegetables		8		12
Margarine		8		6
Sugar and sweets		8		15

Source: Dannhauser et al., 1996

Table 3.6: Sources of "free food" for households from Rural Foundation and non-Rural Foundation farms in the Bloemfontein district.

	Rural Foundation farms (n=259) %	Non-Rural Foundation farms (n=162) %
Vegetable garden	66.7	43.3
Own chickens/eggs	58.5	65.9
From farmer	93.1	89.0

Source: Dannhauser et al., 1996

3.3.2.2 QwaQwa

Oldewage-Theron and Egal (2010) reported the top 20 food items consumed during a 24-hr recall period by a convenience sample of 142 (out of 540) 9 to 13 year old learners from one purposively selected public school. The mean daily intake (although the text states mean portion size) was calculated by dividing the total daily amount of the food consumed by the number of respondents who consumed the specific food item. In Table 3.7, foods are ranked according to total daily intake for the group of respondents. Stiff maize meal porridge, consumed in large quantities and by all but one of the respondents was the top ranked food.

Table 3.7: Top 20 food items consumed by 9 to 13 year old learners in QwaQwa in the Free State

Food item	Total daily intake for the group in g (n=142)	Mean daily intake (g/person)	Learners who consumed the item: number	Learners who consumed the item: %
Maize meal porridge, stiff	35 109	249	141	99.3
Tea, brewed (Ceylon)	18 560	232	80	56.3
Soup (meat and vegetable)[a]	8 050	70	115	81.0
Bread	7 232	113	64	45.1
Milk, full cream, fresh	7 105	203	35	24.6
Chicken, cooked	2 844	79	36	25.4
Maize meal porridge	1 836	153	12	8.5
Scone	1 666	119	14	9.9
Maas	1 518	138	11	7.7
Sausage, pork, cooked	1406	74	19	13.4
Spinach, cooked	1344	56	24	16.9
Fruit juice	1344	168	8	5.6
Potato, cooked	1288	56	23	16.2
Potato, crisps	1222	47	26	18.3
Boerewors	1105	65	17	12.0
Vetkoek	1072	134	8	5.6
Sugar	880	10	88	62.0
Cabbage, cooked	810	54	15	10.6
Gravy (Oxo)	783	29	27	19.0
Chicken feet, cooked	759	69	11	7.7

[a] meat-and-vegetable soup with maize meal porridge were served as part of the National School Nutrition Programme.

Source: Oldewage-Theron & Egal, 2010

Data provided in Table 3.7 shows that ranking foods based on total amount of food consumed by the group does not necessarily represent the proportion of the study population consuming certain foods. For example, sugar was ranked 17th, yet 62% of the children consumed sugar on the day of the survey; versus, e.g., scone that was ranked 8th, but was consumed by only 9.9% of the children on the day of the survey.

3.3.2.3 Farm worker community in Fouriesburg

Kruger et al. (2008) conducted a cross-sectional survey in a farmer community during five seasonal periods, i.e. early summer, late summer, autumn, winter and spring. Data were collected using a questionnaire, focus group discussions, observations and informal individual interviews. Households on the farm had access to land for growing vegetables (although it seemed that they lacked the knowledge and skills to do so). When fruit was in abundance, households were allowed to harvest and preserve for future use. Farm employees received maize meal as payment in kind, ranging from 40 to 160 kg per person per month. Herdsmen received donations of milk and field workers received donations of flour. On Christmas day all employees received mutton.

Shortages of meat and vegetables occurred in the 3rd and 4th week of each month and were replaced by ‘veldt’ (wild) foods gathered from the environment, unpasteurized milk purchased cheaply from the farm, and eggs from the households’ own chickens, if these were available. Food-coping strategies when income was low included buying cheaper foods (e.g. chicken feet and soy mince soup) or less preferred foods (e.g. meat bones); gathering wild foods especially green leafy vegetables; and utilizing seed stock (maize) provision from the farmer as payment-in-kind.

3.3.3 Gauteng

No quantitative data on foods consumed in rural areas were obtained, yet it is acknowledged that the province has a small rural population**.**

3.3.4 KwaZulu-Natal

3.3.4.1 Ndunakazi

Eight papers reported on food intake in Ndunakazi, a rural village bordering The Valley of a Thousand Hills in KwaZulu-Natal. In this section, data are reported per life-stage, from youngest to oldest.

Three studies reported on foods consumed by 4 to 24 month old children. In these studies, different approaches were used to report on the most frequently consumed food items. The first study reported on the frequency of consumption of food items, including cariogenic food items, expressed as the average times consumed per week (Table 3.8; MacKeown & Faber, 2004). In the second study, a set of unquantified food frequency questions was used (Table 3.9; Faber & Benadé, 1999). In the third study, food items reported by more than 5% of the children during a 24-hr recall period was reported, together with average portion sizes and energy contribution per food item towards total daily energy (Table 3.10; Faber & Benadé, 2001).

These three studies showed that 4 to 24 month old children consumed a cereal-based diet with infrequent intakes of food of animal origin, fruits and vegetables. Consumption of meat and chicken increased as the children became older, although the frequency of consumption was still relatively low. These studies further highlight the importance of considering the grouping of foods when interpreting the data. In Table 3.8, vegetables other than vitamin A-rich and fresh fruit were both consumed by more than half of the children, whereas in Table 3.10 frequency of consumption is reported for the individual vegetables and fruit, and these are ranked much lower. Frequency of consumption is reported in both Tables 3.8 and 3.9, but these data is difficult to compare as the time period of the frequency was not specified and the frequency categories differ.

Table 3.8: Foods consumed by more than 5% of 4 to 24 month old children in Ndunakazi

Food Item	% of children consuming the food (n=105)	Weekly frequency of consumption
Soft maize meal porridge	73	5.6
Banana	66	1.4
Crisps / Niknaks	63	3.8
Rice	61	3.1
Bread, brown	60	5.0
Sweets	56	2.7
Vegetable, other than vitamin A rich	52	2.7
Potato	51	1.2
Fresh fruit	51	3.3
Biscuits, with filling	47	3.4
Orange	47	1.3
Pumpkin	45	1.7
Stiff maize meal porridge	43	7.3
Tea with sugar	43	5.2
Cake – plain / muffin	41	2.8
Apple	41	1.3
Cooldrink (carbonated beverages)	37	3.1
Yoghurt- fruit sweetened	35	2.0
Jelly	34	1.6
Samp-and-beans	32	1.5
Imifino	27	1.6
Nestum infant cereal	26	5.6
Ice-cream	26	2.0
Butternut	24	1.7
Orange juice, sweetened	21	4.5
Milk	21	4.5
Cordial (non-carbonated beverages)	20	3.8
Sweet potato	19	2.8
Custard	19	2.3
Popcorn	19	2.2
Pear	16	1.1
Scone	15	2.1
Junior pudding (jarred baby food)	15	1.9
Sugar	13	5.8
Samp	11	1.6
Orange juice, liquifruit	11	3.6
Oats porridge	8	2.5
Grapes	8	-
Chutney (onion / tomato / chili)	8	4.0
Crumpet	7	2.0
Chocolate	7	1.9

Source: MacKeown & Faber, 2004

Table 3.9: Most frequently consumed foods for 4 to 24 month old children in Ndunakazi as determined with a set of unquantified food frequency questions

Foods	Age group	Every day %	Most days %	Once/week %	Seldom %	Never %
Meat	4-12 months	-	2.0	30.0	22.0	**46.0**
	12-24 months	-	3.5	**72.4**	17.2	6.9
Chicken	4-12 months	-	0.0	38.0	16.0	**46.0**
	12-24 months	-	5.2	**67.2**	22.4	5.2
Fish	4-12 months	-	-	0.0	48.0	**52.0**
	12-24 months	-	-	10.3	**65.5**	24.1
Eggs	4-12 months	-	0.0	2.0	**60.0**	38.0
	12-24 months	-	3.5	12.3	**78.9**	5.3
Bread (all)	4-12 months	4.0	**54.0**	10.0	6.0	26.0
	12-24 months	21.0	**64.9**	10.5	1.7	1.7
Maize meal porridge	4-12 months	6.0	12.0	**30.0**	24.0	28.0
	12-24 months	0.0	28.1	**52.6**	10.5	8.8
Nutromeal (maize meal porridge)[1]	4-12 months	**84**	-	-	-	16.0
	12-24 months	**96.5**	-	-	-	3.5
Rice	4-12 months	-	**54.0**	12.0	4.0	30.0
	12-24 months	-	**75.0**	15.8	7.0	1.7
Rice and beans	4-12 months	-	**62.0**	12.0	-	26.0
	12-24 months	-	**86.0**	12.3	-	1.7
Potatoes	4-12 months	0.0	**68.0**	30.0	2.0	0.0
	12-24 months	1.7	**80.7**	12.3	3.5	1.7
Cabbage	4-12 months	-	-	4.0	8.0	**88.0**
	12-24 months	-	-	10.5	28.1	**61.4**
Carrots	4-12 months	-	-	2.0	10.0	**88.0**
	12-24 months	-	-	3.5	8.8	**87.7**
Imifino	4-12 months	-	0.0	10.0	28.0	**62.0**
	12-24 months	-	1.7	31.6	**45.6**	21.0
Pumpkin	4-12 months	-	**57.1**	34.7	6.1	2.0
	12-24 months	-	**71.9**	21.0	5.3	1.7
Spinach	4-12 months	-	-	2.0	26.5	71.4
	12-24 months	-	-	1.7	60.3	37.9
Tomatoes	4-12 months	-	2.0	14.3	**61.2**	22.4
	12-24 months	-	1.7	32.8	**60.3**	5.2
Apple	4-12 months	-	0.0	12.2	28.6	**59.2**
	12-24 months	-	1.7	17.2	**58.6**	22.4
Banana	4-12 months	-	10.2	**46.9**	40.8	2.0
	12-24 months	-	8.6	**48.3**	41.4	1.7
Orange	4-12 months	-	16.3	**71.4**	12.2	0.0
	12-24 months	-	19.0	**67.2**	10.3	3.4

[1] Porridge used in a feeding trial

Source: Faber & Benadé, 1999

Table 3.10: Food items reported by more than 5% of 4 to 24 month old Ndunakazi children during the 24 hr recall period, average portion sizes and energy contribution per food item towards total daily energy intake

Food item	% children (n=50)	Portion size (g)			% energy contribution
		Average	Min	Max	
Oil	80	3	1	8	4
Soft maize meal porridge	68	130	50	400	8
Sugar	68	5	1	10	2
Beans	62	65	30	160	6
Rice	60	53	20	155	5
Phutu	58	115	45	250	6
Hard margarine	56	5	1	20	2
Breast milk	54	-	-	-	31
Pumpkin / butternut	46	70	15	125	2
Tea	36	185	80	180	–
Imifino	26	45	20	80	<1
Potato	26	105	40	170	3
Brown bread	24	60	30	120	3
Formula milk	18	145	50	250	7
White bread (shop & homemade)	16	45	25	100	2
Infant cereal (dry weight)	16	10	3	15	1
Niknaks (a savoury snack)	14	30	30	30	2
Fresh milk	14	80	50	180	1
Non-dairy creamer	12	5	4	4	<1
Orange juice	10	155	50	250	1
Cordials	10	115	50	180	<1
Banana	8	70	25	100	<1
Orange	8	110	60	180	<1
Carbonated cold drink	8	140	90	200	<1
Egg	6	65	50	100	<1
Samp and beans	6	145	120	170	1
Peanut butter	6	5	1	5	<1
Cabbage	6	80	55	115	<1
Mahewu (fermented porridge)	6	185	90	270	1

Source: Faber & Benadé, 2001

Dietary intake was determined for 2 to 5 year old children (n=164) and their caregivers (n=137) using a 24-hr dietary recall and a set of unquantified food frequency questions focusing on animal products and β-carotene rich fruits and vegetables (Faber et al., 2001). Food items reported by more than 5% of the respondents are listed in Table 3.11. The children and their caregivers consumed similar types of food, but portion sizes differed. Both children and caregivers had low intake of animal products, and a lack of variety of foods in the diet predisposed them to low micronutrient intakes. Median dietary intakes were below 50% of the Recommended Dietary Allowance (RDA) for multiple micronutrients.

It should be noted that oil used in the preparation of food was not considered when listing the foods in Table 3.11; whereas in Table 3.9, oil was considered and was the highest ranked food based on the percentage of children who consumed the specific food on the day of recall.

Table 3.11: Most frequently consumed food items for 2 to 5 year old children and their caregivers in Ndunakazi (reported by at least 5% of both the children and the caregivers during the 24-hr recall period)

Food items reported by children (n=164)			Food items reported by caregivers (n=137)		
Food Item	%	portion (g)	Food Item	%	portion (g)
Phutu	77	250	Bread (all)	87	145
Tea	71	170	Tea	86	350
Bread (all)	70	60	Phutu	78	475
Beans (legumes)	56	115	Beans (legumes)	61	190
Rice	53	130	Rice	52	265
Cabbage	37	95	Non-dairy creamer	48	10
Maize meal porridge	32	225	Cabbage	34	160
Potato	29	130	Potato	27	230
Non-dairy creamer	28	5	Imifino	20	165
Banana	26	75	Maize meal porridge	16	350
Orange	26	120	Orange	14	140
Egg (fried or boiled)	25	65	Tomato and onion	12	290
Imifino	18	100	Samp-and-beans	12	480
Pumpkin	12	90	Banana	9	130
Tomato and onion	12	150	Egg (fried or boiled)	7	85
Samp-and-beans	12	265	Fruit juice (mainly orange)	7	255
Milk	10	120	Meat	7	145
Fruit juice (orange)	7	150	Pumpkin	6	150
Meat	6	90	Milk	4	90

Source: Faber et al., 2001

Data collected in 2003 and 2005 highlighted the importance of taking seasonality into account when interpreting food intake data. The 2003 data showed that the majority of households did not have access to butternut for the period April to December; the majority of households did not have access to pumpkin and orange-fleshed sweetpotato during the second half of the year; the majority of households did not have access to carrots and spinach during the first half of the year (Faber & Laubscher, 2008). The effect of seasonal availability on vegetable and fruit intake is reflected in Tables 3.12 and 3.13. Table 3.12 shows the frequency that vegetables and fruit were reported for 2 to 5 year old children during February, May, August and November in 2005 using five repeated 24-hr recalls for each month that dietary data was collected (Faber & Laubscher, 2008). Butternut and pumpkin are reported together, as the food database did not distinguish between these two foods. Table 3.13 shows the percentage of children in Ndunakazi and a neighbouring village (Bhasobha) who consumed dark-green leafy vegetables during the 5-day recall period. Consumption of imifino was reported mostly during the February and November surveys and spinach, a cool weather crop, mostly during the August survey (Faber et al., 2007).

Table 3.12: Number of times that vegetables and fruit were reported during the 5-day repeated recall period for 2 to 5 year old children in Ndunakazi in 2005

	February (n=48)	May (n=47)	August (n=48)	November (n=48)
Fruit				
Apple	34	37	24	50
Banana	42	37	43	21
Grapes	17	-	-	-
Mango	-	-	-	7
Naartjie	-	3	2	
Orange	8	34	44	43
Paw-paw	3	4	20	36
Peach	7	-	-	6
Pear	11	8	9	2
Vegetables				
Cabbage	54	81	71	74
Carrots	4	2	3	9
Pumpkin or butternut	58	40	7	-
Orange-fleshed sweetpotato	3	2	-	-
Imifino[a]	77	20	21	62
Spinach	-	15	63	14

[a]*imifino* is a collection of various dark-green leaves that is eaten as a vegetable; the leaves either grow wild or come from vegetables such as pumpkin, beetroot and sweetpotato
Source: Faber & Laubscher, 2008

Table 3.13: Consumption of dark-green leafy vegetables by 2 to 5 year old children during 2005 as determined by the 5 day repeated 24 hr recall, for the Ndunakazi and Bhasobha villages

Food	February (n=78)	May (n=74)	August (n=75)	November (n=8)
	Percentage of children who consumed dark green leafy vegetables			
All dark-green leafy vegetables	86	36	59	78
Imifino	86	22	20	72
Spinach	0	15	49	14
	Number of times reported (over 5 days)			
Imifino	149	24	25	105
Spinach	0	15	65	16
	Frequency of consumption (over 5 days)			
All dark-green leafy vegetables	2.2	1.4	2.0	2.0

Source: Faber et al., 2007

Food intake was determined for 10 and 11 year old children (Faber at al., 1999). The most frequently consumed foods as determined per food frequency questionnaire are listed in Table 3.14, while the most frequently reported foods over the 24-hr recall period and average portion sizes are shown in Table 3.15.

Foods purchased by more than 60% of households included maize meal, rice, wheat flour, dried beans, sugar, oil, potatoes and samp. Home-produced food by more than 30% of households included chickens, goats, cattle, eggs, pumpkin, imifino, mealies, cabbage and carrots. Production and consumption of vitamin A-rich vegetables were low. A high percentage of households engaged in home gardening, which was practiced mostly for daily food needs (Faber et al., 1999).

Table 3.14: Foods consumed by 10 and 11 year old children in Ndunakazi

% children (n=50)	Foods consumed at least 4 days per week
100	Phutu
90-99	Bread, biscuits/cookies
80-89	Tomato, potatoes
70-79	Mealie, savoury snacks, sweets/chocolate
60-69	Eggs, rice, cold drinks
50-59	Rice and beans, soya, vegetables and fruit
40-49	Meat, chicken, imifino, apple, banana, maize meal porridge
30-39	Pear
20-29	Milk, polony, canned fish, vetkoek, maize-and-beans, cabbage, pumpkin, orange
10-19	Cooked porridge, other than maize meal, samp-and-beans, naartjie, paw-paw, peach
5-9	Liver, fish (fresh), carrots, sweetpotato, avocado, grapes, guava, mango
<5	Green beans, peas, apricot, melon, watermelon

Source: Faber et al., 1999

Table 3.15: Most frequently reported food items for the 24-hr recall period and average portion sizes for 10 and 11 year old children in Ndunakazi

	No of times reported (n=50)	Ave portion size (g)
Bread	67	122
Sunflower oil	64	6
Sugar	62	14
Smart cookie [a]	47	45
Tea	52	266
Rice	37	135
Potato	37	104
Brick margarine	35	11g
Phutu	34	230
Bunny lick/cold drink	34	246
Non-dairy creamer	32	5
Dried beans	31	106
Sweets	27	12
Niknaks	24	36
Fish	23	45

[a] fortified biscuit given daily to the children during school hours
Source: Faber et al., 1999

Dietary intake was determined for 25 to 55 year old females (n=187) using a set of unquantified food frequency questions and a single 24-hr dietary recall (Faber & Kruger, 2005). Food items consumed during the 24-hr recall period are shown in Table 3.16. Generally, the intake of vegetables was low, and the most frequently consumed vegetables were cabbage and imifino. Generally fruit intake was low, and the most frequently consumed fruit were banana, apples and oranges.

Table 3.16: Foods reported during the 24-hr recall period by more than 5% of 25 to 55 year old females in Ndunakazi and average portion sizes

Food Item	% (n=187)	Avg. portion (g)	Food Item	% (n=187)	Avg. portion (g)
Sugar	98	20	Curry sauce	24	205
Tea	80	350	Carbonated drinks	24	360
Phutu	69	510	Mahewu	22	530
Bread-brown	61	155	Orange	18	155
Rice	61	275	Apple	15	157
Non-dairy creamer	43	6	Potato	12	235
Bread-white	40	165	Chicken	12	55
Beans	40	200	Peanut butter	11	20
Egg (fried or boiled)	36	70	Beef	10	125
Soft porridge	31	480	Milk	9	110
Cabbage	30	160	Spinach	9	170
Tomato and onion stew	30	250	Jam	9	45
Banana	30	125	Corn-on-the-cob	7	275
Samp-and-beans	27	540	Pumpkin	7	110
Imifino	27	180	Niknaks	6	30

Source: Faber & Kruger, 2005

3.3.4.2 KwaXimba Tribal Authority, Valley of a Thousand Hills

A cross-sectional survey of 100 households was done from October to December 2008. Households obtained African leafy vegetables from the wild (53%), household yard (52%), riverbank (24%) and planting fields (15%). Ninety-seven percent (97%) of the households consumed African leafy vegetables during the week prior to the survey, while 30% of the households consumed it the day prior to the survey. The preferred African leafy vegetables were Amaranth and Blackjack (Faber et al., 2010).

3.3.4.3 The Valley of a Thousand Hills

Baseline data of a randomized controlled trial included foods consumed by 6 to 12 month old infants (n=475). Usual food intake as determined by a set of unquantified food frequency questions is shown in Table 3.17. Foods consumed during a 24-hr recall period are listed in Table 3.18 (Faber, 2005). The infants had a low intake of animal products and β-carotene-rich fruits and vegetables. The nutrient composition of complementary diet was inadequate, especially for iron, zinc and calcium (Faber & Benadé, 2007).

Table 3.17: Usual food intake of 6 to 12 month old infants in The Valley of a Thousand Hills as determined by an unquantified food frequency questionnaire

	Frequency of consumption by infants (n=505)			
	Most days	Once/week	Seldom	Never
Foods	%	%	%	%
Bread	44	15	13	28
Maizemeal porridge – soft	88	3	2	7
Maizemeal porridge – stiff	23	20	14	43
Maizemeal porridge – fermented	2	10	10	78
Cooked porridge other than maizemeal	4	4	5	87
Infant cereal	52	5	2	41
Rice	32	31	10	27
Potato	43	32	12	13
Fresh milk	5	14	22	59
Milk powder	14	<1	<1	85
Yoghurt	22	39	24	15
Meat	21	22	21	36
Chicken	12	40	13	35
Fish	1	15	13	71
Eggs	38	30	15	17
Beans (legumes)	1	18	23	58
Soya protein	9	21	16	54
Peanut butter	27	31	14	28
Pumpkin	32	30	22	26
Butternut	22	36	19	23
Carrots	3	21	20	56
Dark-green leafy vegetables	10	29	17	44
Cabbage	7	25	17	51
Tomato	4	18	26	52
Apple (mostly cooked)	9	25	19	47
Banana	29	36	16	19
Orange	36	36	17	11
Sugar	50	2	5	43
Biscuits	27	29	15	29
Sweets	8	14	26	52
Savoury snacks	42	35	11	12
Carbonated drinks	12	26	19	43
Tea	23	4	8	65

Source: Faber & Benadé, 2007

Table 3.18: Foods consumed by 6 to 12 month old infants (n=475) in the Valley of a Thousand Hills, as reported during a single 24-hr dietary recall period

Foods consumed by more than 5% of the infants, and average portion size					
Food Item	%	Portion (g)	Food Item	%	Portion (g)
Soft maize meal porridge	82	115	Orange	12	115
Rice	38	45	Banana	9	60
Formula milk	33	20	Yoghurt	9	130
Infant cereals	31	20	Milk powder	9	20
Legumes	24	50	Savoury snacks	9	45
Peanut butter	22	5	Eggs	8	55
Potato	21	80	Bread	8	40
Phutu	17	90	Curry sauce	7	25
Ready-to-eat canned baby foods	17	135	Fresh milk	6	75
Pumpkin, butternut squash	14	80	Chicken	6	30

Source: Faber, 2005

3.3.4.4 Umkhanyakude and Zululand (Nongoma and Pongola sub-districts)

A cross-sectional survey including 1988 randomly selected households with children younger than five years was done in 2003 (Smuts et al., 2008). Table 3.19 shows the sources where households obtained their food from during the month prior to the survey, as well as the percentage of households who had a home garden and/or livestock. The majority of households obtained their food from shops. Although approximately half of the households reportedly had a home garden, only 12% obtained food from the garden the month prior to the survey, probably reflecting that the gardens do not provide food throughout the year. Although many households owned livestock, it was not a major source of food for household consumption.

Qualitative dietary data was collected for 2 to 5 year old children, using a set of unquantified food frequency questions that focused on foods of animal sources, yellow/orange-fleshed fruit and vegetables and dark green leafy vegetables. Frequency of consumption of these foods was low, as is shown in Table 3.20. Sources of yellow/orange-fleshed fruit and vegetables and dark-green leafy vegetables for those children who consumed the specific food are also shown in Table 3.20 (please note that the values given in the Table are expressed as a percentage of those households who consumed the specific food). When consumed, carrot, pumpkin/butternut and spinach were grown in the home-garden by a significant number of households. Home-gardens were also a source for tropical fruit (mango and paw-paw).

Table 3.19: Sources where households in Umkhanyakude and Zululand districts in KwaZulu-Natal obtain their food from, using the month prior to the survey as guide, and ownership of a home garden and/or livestock

		Zululand		
	Umkhanyakude (n=996) %	Nongoma (n=495) %	Pongola (n=497) %	All (n=1988) %
Source of food the past month				
Bought/shops	75	74	80	76
Own home garden	17	2	13	12
Gifts	6	8	7	7
Payment in kind	4	8	5	6
Begged	5	7	4	5
Food aid/welfare/NGO	2	2	2	2
Own live stock	1	<1	5	2
Communal garden	1	1	2	1
Borrowed	1	1	1	1
Household owns a home garden or livestock				
Have livestock	67	72	69	64
Have a home garden	56	43	37	49
Main function of home garden				
Daily food needs	82	86	75	83
Income	9	8	17	10
Daily food needs and income	6	5	6	5
Other	2	1	2	2

Source: Smuts et al., 2008

Table 3.20: Usual dietary intake of animal foods, yellow/orange-fleshed fruit and vegetables and dark-green leafy vegetables for 2 to 5-year old children from two districts in KwaZulu-Natal as determined by a set of unquantified food frequency questions, and sources of these foods

		Umkhanyakude (n=631) %	Zululand: Nongoma (n=247) %	Zululand: Pongola (n=317) %	All (n=1222) %
Eggs	At least four days per week	19	33	42	28
	Approximately once per week	8	16	20	13
Meat	At least four days per week	14	43	35	26
	Approximately once per week	20	17	30	22
Chicken	At least four days per week	19	32	38	27
	Approximately once per week	21	29	32	25
Fish	At least four days per week	22	17	21	21
	Approximately once per week	17	15	18	17
Milk	At least four days per week	19	55	55	37
	Approximately once per week	6	12	22	12
Carrots	At least four days per week	9	8	13	9
	Approximately once per week	5	6	13	7
Pumpkin / butternut	At least four days per week	26	14	36	26
	Approximately once per week	13	20	22	17
Spinach	At least four days per week	36	20	43	34
	Approximately once per week	16	14	24	18
Imifino	At least four days per week	50	15	31	37
	Approximately once per week	12	13	22	15
Mango	At least four days per week	14	16	8	13
	Approximately once per week	6	6	14	8
Paw-paw	At least four days per week	16	11	5	12
	Approximately once per week	9	4	10	8
Sources, expressed as a percentage of children who consumed the food					
Carrots	*n*	*248*	*100*	*127*	*475*
	Shops	66	67	83	71
	Home garden	33	29	10	26
	Community garden	1	4	7	3
Pumpkin/butternut	*n*	*444*	*200*	*244*	*888*
	Shops	53	72	68	62
	Home garden	46	26	24	36
	Community garden	1	1	7	2
Spinach	*n*	*468*	*193*	*271*	*932*
	Shops	47	71	79	61
	Home garden	52	26	15	36
	Community garden	1	3	6	3
Mango	*n*	*376*	*118*	*145*	*639*
	Shops	56	99	91	72
	Home garden	32	1	6	20
	Community garden	12	0	3	8
Paw-paw	*n*	*351*	*83*	*118*	*552*
	Shops	56	96	89	69
	Home garden	37	4	7	25
	Community garden	7	0	4	6

Source: Smuts et al., 2008

3.3.4.5 Rural northern Natal

Dietary diversity was assessed for 381 children aged between 6 and 12 months within a randomized controlled trial. For more than half of the observed child weeks, no fruit or vegetable was consumed. The authors mention that little subsistence farming was done in the study area, explaining the low intakes of fruit, vegetables and animal-source foods. The reliance on purchased foods may also explain why no seasonal variation in dietary diversity was found (Mpontshane et al., 2008).

3.3.4.6 Watershed

Amaranth and pumpkin leaves were shown to be the most preferred traditional leafy vegetables (Vorster, 2007).

3.3.5 Limpopo Province / Northern Province

3.3.5.1 Rural female students of the University of the North, Sovenga

Data was collected in February 1994 for 74 rural students using a quantified food frequency questionnaire. Foods consumed were grouped into food groups (Table 3.21). Preferred foods included maize meal porridge with tomato and onion sauce. Wild spinach and pumpkin were the most common vegetables. Legumes were popular as a side dish. Sour milk gruel (motogo), tea and sorghum beer were the most common local drinks. Chicken was very popular and consumed at least twice a week by most families (Steyn et al., 2000).

Steyn and co-workers (2001) reported that wild-growing leafy vegetables seem to be widely and frequently consumed in the Northern Province. This was further confirmed by the observation that wild spinach and pumpkin where the most common vegetables consumed by rural female students of the University of the North (Steyn et al., 2000).

Table 3.21: Mean (SD) daily food consumption (grams) of black female students in terms of food groups

	Rural students (n=74)			Rural students (n=74)	
Food group	Mean	(SD)	Food group	Mean	(SD)
Milk	162.9	(146.2)	Fats/oil	33.8	(33.3)
Eggs	54.8	(45.3)	Confectionery/sweets	183.7	(186.9)
Meat	108.1	(79.0)	Fruit	593.4	(508.7)
Fish	24.0	(27.2)	Vegetables	156.8	(97.3)
Legumes	18.9	(32.2)	Sauces	44.6	(47.9)
Nuts	0.6	(2.4)	Beverages	225.2	(213.1)
Cereals	569.1	(293.1)			
Rice	50.2	(46.1)			
Maize meal	297.7	(256.9)			
Whole maize	49.2	(41.2)			
Wheat products	246.9	(112.3)			

Source: Steyn et al., 2000

3.3.5.2 Dikgale

The influence of seasonal change on dietary intake of an adult population in a rural area was determined in a cross-sectional survey during which data were collected in June 1997 en February 2008 (Steyn et al., 2001). Nutrient intakes were reported for the two seasons, with women having greater intakes for most of the nutrients in summer; while there was little difference over seasons for men. Foods appearing most frequently in the diet (see Table 3.22) were however not reported separately for the two seasons.

Table 3.22: Food items appearing most frequently in the diet of Dikgale adults

Food item	No of times item occurred	Average amount per day (g)	Food item	No of times item occurred	Average amount per day (g)
Maize porridge	1212	592.8	Hard margarine	72	12.9
Tea	659	425.3	Fried egg	44	104.9
White sugar	637	20.1	Sorghum beer	43	1313.0
Brown bread	430	163.2	Cooked cabbage	37	103.9
Morogo	314	135.4	Cold drink	35	297.7
Chicken	228	92.3	Peanut butter	35	21.8
Non-dairy creamer	154	7.8	White rice	32	314.2
Tomato and onion	133	89.0	Banana	30	148.2
Dry beans	119	214.5	Whole milk	28	217.8
White bread	104	161.5	Jam	27	20.6

Source: Steyn et al., 2001

3.3.5.3 Sekhukhune district

Food groups consumed by a randomly selected sample of 499 households in Sekhukhune are shown in Table 3.23. Maize and maize products were the most frequently consumed foods, and legumes the least frequently consumed foods. For the majority of the households, purchased food was the main source for foods. Foods were mostly bought from supermarkets in town (47%), small trading stores situated less than 1 km from home (29%) and small trading stores situated more than 1 km from home (22%). Significantly own production was the main source for vitamin A rich fruit and vegetables for only 7% of the households (Faber et al., 2009).

Table 3.23: Percentage of households that consumed foods from a specific food group the previous day, and the frequency of consumption over the past 7 days

Food group	% households who ate it yesterday (n=498)	No. of days consumed the past 7 days Median (Q1; Q3)
Maize and maize products	99.2	7 (7; 7)
Beverages	87.6	7 (6; 7)
Sugars	85.1	7 (5; 7)
Meat, poultry and fish	69.5	3 (1; 5)
Cereals other than maize	68.1	3 (1; 6)
Roots and tubers	67.5	3 (2; 5)
Oils and fats	65.3	5 (1; 7)
Vitamin A-rich fruit and vegetables	60.0	3 (1; 5)
Vegetables other than vitamin A-rich	56.4	3 (1; 4)
Dairy products	33.9	1 (0; 4)
Fruit other than vitamin A-rich	28.2	1 (0; 3)
Eggs	27.4	1 (0; 3)
Legumes, nuts and seeds	18.5	0 (0; 2)

Source: Faber et al., 2009

According to Masekoameng and Molotja (2003), porridge made with either maize meal or sorghum is the most preferred food by women, while meat is the most preferred food for men. Foods disliked by men included vegetables such as cabbage and indigenous leafy vegetables, and milk.

A cross-sectional survey of 100 households done in October to December 2008 showed that African leafy vegetables were available and easily accessed by the households. Most of the households (94%) obtained African leafy vegetables from the wild, while 11% obtained the leaves from the planting fields, and 1% from a community garden. All the households consumed African leafy vegetables during the month prior to the survey, and 99% consumed it the day prior to the survey. The most preferred African leafy vegetables were Amaranth and Spider plant (Faber et al., 2010).

In seven villages, the following crops were observed in local gardens: sorghum, millet, mung beans, njugo beans, cowpea, pumpkin, sweet reed stock melon or citron, *boontjies*, watermelon and gourds. Cultivated vegetables included beetroot, carrots, onions, cabbage, spinach, Chinese spinach, sweetpotatoes and chilies. Livestock farming included chickens, goats, sheep and cattle. Indigenous foods included indigenous leaves, thelele, marula leaves and fruit (Masekoameng & Molotja, 2003).

3.3.5.4 Vhembe district

Breastfeeding and weaning practices were determined for 185 infants younger than 12 months (Mushapi et al., 2008). At the time of the survey, 143 (77%) had been introduced to solid foods. The ten top foods consumed by these infants are shown in Table 3.24. Some foods are listed separately (e.g. soft porridge) while other foods were grouped (e.g. fruit, vegetables).

Table 3.24: Top ten foods fed by mothers to their infants in Vhembe district

Food item	% children eating the food (n=143)	Food item	% children eating the food (n=143)
Soft porridge	71.0	Stiff porridge	33.0
Fruit	53.4	Chips or sweets	30.0
Soup	40.4	Chicken	30.0
Tea	37.0	Baby food (Nestum / Purity)	29.0
Vegetables	36.0	Bread	27.0

Source: Mushapi et al., 2008

Tshihwanambi (2007) did a cross-sectional survey focusing on consumption patterns of vitamin A-rich foods of 10 to 13 year old children (n=155) in Vyeboom. Vegetables were obtained from home-gardens by 38.1% of households, while 61.9% obtained wild vegetables from the veld, bush or cultivated lands. The majority of children consumed wild vegetables one to three days per week, mostly Wild jute (*Corchoris tridens*), Amaranth and Blackjack (*Bidens pilosa*). Fruits eaten mostly were apples, bananas and oranges. Most children ate wild fruit, obtained from farms, bush and mountain at least once a week. The most popular wild fruit was num-num (*Carrisa edulis*). Vegetable and fruit consumption was affected by seasonal availability and accessibility.

Mbhenyane and co-workers (2005) determined habitual dietary intake for 37 students (18 males and 19 females) using a quantified food frequency questionnaire. On average, the students consumed 59.5 ± 12.7 different food items/dishes, with males having less variety of foods than the females (54.7 ± 19.0 versus 64.0 ± 12.7). It should however be noted that a specific food being prepared in different ways was reported per preparation method (e.g. egg boiled and egg fried) and some descriptions were unusual (e.g. peanuts associated with a samp and bean dish). The most frequently consumed food items are listed in Table 3.25.

Table 3.25: Foods consumed by at least 10% of health students (n=37) in the Vhembe district, expressed as the percentage of individuals who consumed the food item

Food item	*%*	*Food item*	*%*	*Food item*	*%*
Starchy foods					
Maize-meal porridge, stiff	100	Maltabella porridge, soft	65	Vetkoek	49
Rice, white	92	Corn on the cob	65	Oats	38
Bread, brown	89	Samp and beans	62	Cornflakes	35
Maize-meal porridge, soft	81	Macaroni/spaghetti	51	Crackers	16
Bread, white	70				
Meat and meat products					
Chicken	95	Fish, canned pilchards	51	Tuna, in oil	19
Polony	92	Pork	47	Kidney, ox	16
Fish, fried	81	Hamburger	43	Rabbits	11
Beef	78	Chicken giblets	41	Egg, fried	11
Egg, boiled	70	Vienna sausage	32	Fish cakes	11
Chicken feet, stew	65	Liver, ox fried	32	Ham	11
Mutton	65	Boerewors, sausage	31	Bacon	11
Mopani worms	60	Canned beef	27		
Tripe, ox	54	Locusts	24		
Milk and milk products					
Whole milk	100	Cream, fresh	22	Condensed milk	11
Yoghurt, fruit	59	Sour milk	19		
Cheddar, cheese	57	Whole milk powder	14		
Legumes					
Peanuts (samp bean dish)	59	Dried beans (varieties)	54		
Peanuts, roasted, salted	54	Peanuts & raisins	24		
Fruits					
Apple	92	Mango, fresh	51	Grapes	38
Orange	84	Guava	43	Peach, fresh	24
Banana	81	Apricot, canned	41	Wild fruit	22
Orange juice	76	Peach, canned	41	Apricot, canned	19
Vegetables					
Tomato in gravy	100	Pumpkin	84	Potato, mashed	30
Onion	100	Lettuce salad	62	Potato chips	30
Cabbage, cooked	89	Sweet potato, baked	62	Potato, roasted	16
Potato, boiled	89	Carrot, raw	57	Potato salad	16
Spinach, cooked with oil	84	Sweet potato, cooked	35	Carrot cooked	12
Beetroot	84	Tomato, raw	34		
Miscellaneous					
Oil, sunflower	100	Peanut butter	70	Sweets	41
Salt	100	Maheu (maize meal drink)	59	Jelly	41
Sugar	100	Potato chips, snack	54	Scones, homemade	38
Tomato sauce	96	Cornish pie	54	Soup, packet	24
Margarine	84	Chocolate	51	Cake, commercial	22
Tea	76	Coffee	51	Butter	19
Custard	76	Jam	43	Sausage roll	19
Ice-cream	76	Cookies, biscuits	65	Beer, commercial	19
Atchaar, mango	73	Cold drink, carbonated	59	Bovril	14
Mayonnaise	70	Pudding	43	Meat spread, ham, bacon	11

Source: Mbhenyane et al., 2005

3.3.5.5 Rural villages in the Central Region of Limpopo Province

Mamabolo and co-workers (2006) reported the most frequently consumed food items for a cohort of children at ages 1 and 3 years as determined by a food frequency questionnaire and 24-hourr recall. Results are shown in Table 3.26. Comparison between results obtained through the food frequency and 24-hr recall shows differences in the foods most frequently consumed. For example, when using the food frequency questionnaire, sweets are the third most frequently consumed food item, while according to the 24-hr recall, it is no 21 on the list.

Table 3.26: The 30 major food items most frequently consumed by the children at 1 and 3 years

Ranking	QFFQ at 1 year (n=156)	QFFQ at 3 years (n=162)	24-hr recall at 3 years (n=162)
1	Potatoes	Sugar	Maize meal
2	Bread	Maize meal	Sugar
3	Maize meal	Sweets	Tea
4	Milk	Crisps	Bread
5	Banana	Potatoes	Chicken
6	Sugar	Bread	Milk
7	Eggs	Cabbage	Cabbage
8	Tea	Fish	Tomato and onion
9	Chicken	Tea	Banana
10	Oranges	Banana	Oranges
11	Tomato and onion	Oranges	Crisps
12	Cabbage	Rice	Eggs
13	Crisps	Tomato and onion	Soups
14	Mabella	Cookies	Beef
15	Spinach	Apple	Potatoes
16	Sweets	Eggs	Mabella
17	Fish	Spinach	Bread, white
18	Pumpkin	Atchaar	Rice
19	Cookies	Chicken	Spinach
20	Rice	Cool drink	Margarine
21	Yoghurt	Samp	Sweets
22	Soups	Beef	Fish
23	Apple	Milk	Apple
24	Cool drink	Vetkoek	Pumpkin
25	Beef	Margarine	Beetroot
26	Margarine	Squash	Vetkoek
27	Macaroni	Macaroni	Squash
28	Fruit juice	Soya	Avocado
29	Soya	Soups	Cookies
30	Vetkoek	Yoghurt	Peanut butter

QFFQ – quantified food frequency questionnaire;
Source: Mamabolo et al., 2006

Theron and co-workers (2007) purposely selected two rural villages in the Limpopo Province, namely Sekuruwe and Molekane. Dietary information was collected for 58 children aged 12 to 24 months (29 stunted pair-matched with 29 non-stunted) during November 1998. The most frequently consumed foods are listed in Table 3.27.

Table 3.27: The 30 most frequently consumed foods for 12 to 24 month old children in Sekuruwe and Molekane in the Limpopo Province

	Total amount per day		Average g/day per person	
Food item and ranking	Stunted (n=29)	Non-stunted (n=29)	Stunted (n=29)	Non-stunted (n=29)
Maize meal (cooked)	10606	10 317	366	356
Tea	4547	5030	157	173
Potato, mashed	1642	1579	57	54
Mahewu / magou	1577	558	54	19
Milk, whole, fresh	1214	464	42	10
Toppers	1028	690	35	24
Maize, cooked, corn-on-the-cob	938	895	32	31
Soup powder	923	872	32	30
Cold drink, carbonated	734	787	25	27
Bread / rolls, brown	723	1402	25	48
Egg, fried in sunflower oil	513	511	18	18
Cabbage, cooked	510	475	18	16
Cold drink, squash	493	766	17	26
Apple	492	643	17	22
Macaroni / spaghetti	460	907	16	31
Sugar	429	452	15	16
Maize rice / samp	421	237	15	8
Banana	376	524	13	18
Milk, skim, fresh	350	186	12	6
Rice	329	607	11	21
Beans, broad, dried, cooked	323	510	11	18
Fish, pilchard in tomato sauce	301	304	10	10
Non-dairy creamer	292	307	10	11
Vetkoek	292	291	10	10
Tomato, boiled, canned	291	235	10	8
Maltabella porridge	1245	1955	43	67
Bread/rolls white	245	277	8	10
Tripe, beef, cooked in milk	178	437	6	15
Beef, chuck, braised	169	186	6	6
Baked beans	165	113	6	4

Source: Theron et al., 2007

3.3.5.6 Arthurstone, Mars and Glenroy (three rural villages)

Vorster (2007) did a cross-sectional descriptive study to determine the utilization of the five most important traditional leafy vegetables. The most preferred leafy vegetables (named by at least 50% of the respondents) in Arthurstone were *Cleome gynandra, Vigna unguilata* (cowpea), pumpkin leaves, *Momordica balsamina* (cucurbit) and *Chorcorus sp*. In Mars and Glenroy the most preferred leafy vegetables were *Cleome gynandra, Vigna unguilata* (cowpea) and pumpkin leaves.

In a rural community in the central region of the Northern Province (Tiberius, 60 km west of Polokwane) only 9% of the respondents reportedly ate fruit daily (Peltzer, 2002).

3.3.5.7 Bushbuckridge

Hunter et al. (2007) collected data from 240 households in May-December 2004 with the aim to determine whether households affected by the shock of death of a family member differed in their use of local environmental resources. Food acquisition for the 240 households is presented in Table 3.28. The results of the study suggest that with the death of a male wage-earner in the household, wild foods may replace previously purchased foods.

Table 3.28: Food acquisition by 240 households in Bushbuckridge

	% households
Food gathered from the bush	
Gather herbs (e.g. Corchorus)	67
Gather fruit (e.g. marula)	27
Gather insects	20
Grow crops on own plot	%
Grow maize	21
Grow crops other than maize	58
Grow fruit	25
Grow vegetables	40
Grow other foods (mostly groundnuts, peanuts)	13

Source: Hunter et al., 2007

3.3.6 Mpumalanga Province

No quantitative studies reporting on food intake in rural areas were identified.

Feeley and co-workers (2011) conducted an explorative study that focussed on fast foods sold by vendors in three rural villages. The vendors sold a limited range of fast foods because of restricted resources, customer preferences and difficulty in keeping food fresh (no refrigeration available). The most common fast foods sold were mostly unhealthy foods, i.e. chips and vetkoek, followed by kotas. Other foods sold by the vendors included bread, polony, atchar, chakalaka, boiled eggs and fried fish.

3.3.7 Northern Cape Province

No quantitative studies reporting on food intake in rural areas were identified.

3.3.8 North West Province

3.3.8.1 THUSA study

Foods consumed by the rural and farm strata from the THUSA study are shown in Tables 3.29 and 3.30.

Table 3.29: Food items consumed by 85% and more of 15 to 65 year old participants of the RURAL stratum of the THUSA study in the Northwest Province

	Males (n=194)				Females (n=290)		
	%	Portion size (g)			%	Portion size (g)	
Food item		Mean	(SD)	Food item		Mean	(SD)
Sugar, white	100	32.3	(33.7)	Maize meal, porridge	100	450	(350)
Maize meal, porridge	98	550	(388)	Sugar, white	98	35	(40)
Sunflower oil	98	3.4	(2.2)	Onion, cooked	98	8	(7.1)
Onion, cooked	97	8.2	(6.6)	Rice, white	97	35	(36)
Tomato, cooked	92	9.6	(7.4)	Cabbage, cooked	92	8	(10)
Rice, white	95	36	(27.3)	Sunflower oil	95	3.5	(3.8)
Bread, white	93	26	(35)	Tomato, cooked	93	10	(10)
Margarine, brick	91	3.3	(4.5)	Bread, white	91	27	(36)
Apple	91	29	(40)	Margarine, brick	91	3.5	(4.0)
Milk, fresh whole	85	146	(149)	Samp	85	38	(41.4)

Source: MacIntyre et al., 2002

Table 3.30: Food items consumed by 85% and more of 15 to 65 year old participants of the FARM stratum of the THUSA study in the Northwest Province

	Males (n=109)				Females (n=148)		
Food item	%	Portion size (g)		Food item	%	Portion size (g)	
		Mean	(SD)			Mean	(SD)
Maize meal, porridge	100	595	(450)	Maize meal, porridge	99	530	(528)
Sugar, white	95	36	(31)	Sugar, white	97	30	(29)
Rice, white	90	32.1	(31)	Rice, white	95	36	(31)
Sunflower oil	89	2.8	(2)	Cabbage, cooked	93	7.3	(8.0)
Milk, fresh, whole	89	315	(255)	Onion, cooked	93	6.9	(6.3)
Bread, white	87	28	(33)	Sunflower oil	88	3.3	(2.3)
Onion, cooked	85	7.7	(7)	Bread, white	87	35	(42)
				Tomato, cooked	86	9.1	(8.5)
				Margarine, brick	85	3.6	(4.6)
				Banana	82	16	(25)

Source: MacIntyre et al., 2002

3.3.8.2 Ventersdorp district

Focus group discussions showed that farm workers could buy subsidized food such as fresh milk, meat, maize meal, eggs, poultry or vegetables depending on the type of farming the farm was engaged in (Kruger et al., 2006).

3.3.9 Western Cape Province

3.3.9.1 Paarl, Ashton, Caledon, Velddrif, St Helena Bay

Dietary intake was determined for 12-year old children in non-fruit canning and fruit canning areas using a repeated 24-hr dietary recall (Feb-March 2001). The ten most frequently consumed foods are listed in Table 3.31. As reflected in the National Food Consumption Survey, foods consumed in the

Western Cape are different to the rest of the country, but the diet remains high in starchy foods and low in vegetables and fruit (Witten, 2002).

Table 3.31: The ten most frequently consumed foods ranked in descending order by the number of consumers and the percentage contribution to total energy intake for children of non-fruit canning and fruit canning areas in the Western Cape

	Non-fruit canning areas (n=200)		Fruit canning area (n=72)	
Rank	Item	% energy contribution	Item	% energy contribution
1	Sugar, white	5.5	Sugar, white	4.4
			Rice, white	3.9
2	Bread/rolls, white	11.6	Margarine, brick / hard	5.1
3	Margarine, brick / hard	4.9	Water	N/A
4	Rice, white	2.5	Bread / rolls, white	9.4
5	Coffee, brewed/instant	N/A	Snack, savoury (chips)	3.5
6	Snack, savoury (chips)	4.6	Coffee, brewed / instant	N/A
7	Cold drink, squash	1.0	Cold drink, squash	0.8
8	Water	N/A	Chicken, meat & skin	3.5
9	Cold drink, carbonated	2.7	Potato sautéed in sunflower oil	6.4
10	Chicken, meat & skin	3.5	Cold drink, carbonated	0.3

Source: Witten, 2002

3.3.9.2 Stellenbosch district

Krige and Senekal (1997) determined the nutritional status of 4 to 6 year old children residing on farms that had a crèche through a cross sectional survey. The mean intakes from the different food groups for week days and weekend days are given in Table 3.32. Results showed a poor dietary variety, with low intakes of meat, milk, vegetables and fruit. Intake during the week was better compared to that over the weekend, probably because of the meals served at the crèches.

Table 3.32: Mean intake (±SD) from the food groups by 4 to 6 year old children in the Stellenbosch district

Food group	Minimum recommendation	4 to 6 year old children (n=63) Week day	Weekend day
Milk	500 mL	167.78 ± 221.15	85.32 ± 143.59
Meat	2 portions	1.78 ± 1.37	1.58 ± 1.08
Cereal	4 portions	8.86 ± 3.45	4.65 ± 2.10
Vegetables and fruit	4 portions	2.66 ± 1.68	0.76 ± 0.85
Fat	20 mL	33.25 ± 14.73	25.77 ± 13.70

Source: Krige & Senekal, 1997

3.3.10 National data

A national survey that included 3287 adults showed that overall the majority of adults consumed a diet of low dietary diversity (Labadarios et al., 2011). This is in line with the low dietary diversity reported for children (Steyn et al., 2006). Food groups consumed by adults in rural and tribal areas are shown in Table 3.33. The least frequently consumed food groups were vitamin A rich vegetables and fruit, fruit other than vitamin A rich, eggs and legumes.

Table 3.33: The percent adults having consumed an item from the food groups on the day of recall (single 24-hr dietary recall).

Food group	Tribal (n=599) %	Rural (n=355) %
Cereals, roots and tubers	100	100
Vitamin A rich vegetables and fruit	14	14
Fruit other than vitamin A rich	9	15
Vegetables other than vitamin A rich	51	50
Legumes and nuts	23	17
Fats and oils	26	42
Meat / poultry / fish	55	65
Dairy	27	45
Eggs	11	17

Source: Labadarios et al., 2011

Although the National Food Consumption Survey (NFCS) conducted in 1999 (Labadarios et al., 2000) and the NFCS-Fortification Baseline (NFCS-FB) of 2005 (Maunder et al., 2007) did not disaggregate the data in such a way that food intake of rural or poor respondents can be extracted, the former does provide information for each of the nine provinces and for the country as a whole. A graphic poster presentation hereof has been compiled and is presented in Appendix A.

In the NFCS-FB procurement of the foods which have to be fortified in South Africa was investigated. Overall, the results show that rural South African households primarily purchase maize, wheat flour, bread and salt (Maunder et al., 2007).

Maize: All in all, about 30% of the maize was sifted raw (white) and about the same percentage was special raw (enriched). Across the provinces the overall pattern of procurement was similar, except that in the Northern and Western Cape slightly lower percentages of households procured maize (77.6% and 86.2% respectively). Mpumalanga had the highest percentage "farm grown and milled on the farm" (1.7%). [The NFCS of 1999 showed that for 11% of maize-consumers in the Eastern Cape, the maize was homegrown maize (11%); 17% of maize-consuming households in the Free State received maize as payment]

Wheat flour: Cake flour made up about 65% of the total wheat flour procurement, and white bread flour about 24%. Differences in total wheat flour procurement across provinces were noted, ranging from 52.8% for Mpumalanga to 91.99% in the Western Cape.

Bread: Brown bread constituted 79% off the bread acquisition. Overall procurement was common (nationally about 84% of the rural participants procured bread), but there was considerable variation among provinces: from 44.9% in the Northern Cape to 98.8% in the Western Cape.

Table 3.34 is a summary of the findings regarding the sources of these foods, and highlights that amongst rural South Africans practically all maize, wheat flour, bread and salt is purchased.

Table 3.34: Consumption and source of fortified foods by rural South African households (n=1061) (Values are %, unless otherwise indicated)

		Maize	Wheat flour	Bread	Salt
Number (%) procuring for consumption		1047 (98.7)	833 (78.5)	888 (83.7)	1024 (96.5)
Source	Purchased	96.3	99.3	98.3	96.2
	Home-grown / milled elsewhere	0.7	-	0.1	-
	Farm grown / milled on farm	0.5	0.1	0.1	0.4
	Home grown and home milled	0.5	0.1	0.2	0.1
	Food parcels	0.4	0.2	0.3	0.7
	Donated	0.4	-	-	0.7
	Part of pay	0.4	-	-	0.6
	Homemade	0.8	0.1	1.6	0.2
	Other	0.2	-	0.1	0.9

Source: NFCS-FB (Maunder et al., 2007)

Cities and larger towns typically have a supermarket that sells a wide selection of healthy food choices. In small towns the local food store is usually small and has a limited choice of healthy foods (Temple et al., 2011).

3.3.11 Foods consumed outside the household

3.3.11.1 National School Nutrition Programme

The National School Nutrition Programme (NSNP), formerly known as the Primary School Nutrition Programme (PSNP) was introduced in 1994 as one of the Presidential flagship projects under the Reconstruction and Development Programme. In 2004 the Department of Education, now known as the Department of Basic Education (DBE) took full responsibility of the programme.

The NSNP has three components, i.e. school feeding, Sustainable Food Production in Schools (SFPS) and Nutrition Education (NE). The current NSNP guidelines state that that the school meal should provide one third (33%) of the recommended dietary allowance (RDA; 7-10 y) for energy, zinc, calcium, iron and vitamin A (Department of Education, 2008b). The National Food Consumption Survey of 1999 showed that half of the children consumed less than half the required amount for these four micronutrients (Labadarios et al., 2000). The 2011-12 Conditional Grant Framework specifies that fruit/vegetables should be served daily varying between green and yellow/red; a variety of protein should be served weekly; and pilchards should be served at least once per week (fresh milk/maas can replace pilchards where pilchards are not socially acceptable. Furthermore the DBE has on its website a diversity of culture-specific recipes for the different provinces.

By 2007/8 a total of 6503 schools nationally had school food gardens, which is a steady increase from the 3058 gardens in 2004/5. Provinces with the most school food gardens were KwaZulu-Natal (1607) and the Eastern Cape (1211), followed by Gauteng (854), Limpopo (752) and Mpumalanga (751). Low numbers of school food gardens were reported for the Northern Cape (253) and Western Cape (258) (Department of Education, 2008c). Challenges in establishing and sustaining school food gardens include insufficient knowledge and skills to manage the garden effectively a lack of basic resources such as water, fencing to prevent theft and vandalism, seed, and garden implements; poor quality of soil; harsh climatic conditions; pest and disease infestation; a lack of support and commitment from school governing bodies and parents; and seasonality in planting and the challenge of growing sufficient vegetables to supply food in schools with large enrolment (Castle & Bialobrzeska, 2009; Department of Education 2008a, 2008c; Public Service Commission, 2008).

3.3.11.2 Other sources of food

Observations and circumstantial evidence suggest that among the rural poor in South Africa the international trends of increasing consumption of non-home-prepared foods may also apply. The food environment – referring to community-level organisations and food resources (McKinnon et al., 2009) – of this target group cannot be separated from the nutrition transition experienced by the country as a whole (Crush et al., 2011). Away-from-home consumption that comes to mind includes school tuck shops (kiosks), more or less formal street vendors and fast food establishments, and the intakes during social (community) gatherings, for example associated with funerals. In addition, feeding schemes (beyond the NSNP) may be a source food. Overall, the “outside” foods may be nutritious or less healthy (high in fat and / or sugar). Some of these are mentioned in more detail in Chapter 4.

3.4. IDENFICATION OF GAPS IN CURRENT KNOWLEDGE AND CONCLUSION

3.4.1 Identification and discussion of knowledge gaps

The strength of the evidence in this report for a conclusion on food intake of the rural poor of South Africa is affected by the following (limiting) factors.

3.4.1.1 Lack of current, nationally representative food intake data for individuals

The absence of a national food and nutrition surveillance system makes it is difficult to identify periods of food shortages related to factors such as seasonality, periods prior to pay outs of social grants and shocks at household level (e.g. funeral costs or migration of an income earner) all of which have been shown to impact on household food security (Ellis, 2003).

The only large scale study performing individual dietary assessment on a national scale was the National Food Consumption Survey (NFCS) conducted in 1999 (Labadarios et al., 2000). In that study the food intake data were not disaggregated in such a way that rural or poor respondents can be extracted. In the more recent national nutrition survey, the NFCS-Fortification Baseline (NFCS-FB) of 2005 (Labadarios, 2007), the nutritional status differed from the 1999 study. Although comparisons between studies should always be done cautiously, it can be speculated that in the interim period food intake has changed, implying that a secondary analysis of the 1999 data set for the rural poor may yield outdated information.

The lack of current, nationally representative data need not be an absolute requisite for describing current food intake of the rural poor of South Africa. Regional differences, driven by aspects such as climate and culture, may play an important role in specific food choices, in particular in respect of non-staples. Thus smaller scale studies could well be particularly valuable for capturing diversity and describing dietary intake in more depth.

3.4.1.2 Non-representative coverage by smaller scale studies

Geographical coverage
The national studies (NFCS, NFCS-FB) have pointed to differences in nutritional status among the provinces, suggesting the possibility of differing food intake. The smaller scale studies, do, however, not cover all the provinces to a comparable extent. Equally, within province coverage is not uniform.

Certain sites of KwaZulu-Natal (e.g. Ndunakazi) are comprehensively researched and reported. In Limpopo Province a number of studies cover selected sites. In the Free State, Eastern Cape, North West and Western Cape Provinces a few studies report on food intake, but no information was available for Mpumalanga, the Northern Cape and Gauteng Provinces.

Coverage of ethnic / cultural groups
One of the factors influencing food intake is ethnicity or culture. This is evident from culture-specific consumption or preparation of specific food items or dishes in South Africa, such as mopanie worms or specific African leafy vegetables, and the preparation thereof.

Coverage of all stages of the life cycle
In the Integrated Nutrition Programme specific vulnerable groups are highlighted. This has contributed to a focus on these individuals in current nutrition research. Households do however, not only consists of these vulnerable people. Extrapolating these findings to the general rural population may introduce error.

The vast majority of the studies identified focus on infants and children. Non-elderly adults were assessed by a few studies. Two studies investigated food intakes of households as a unit.

3.4.1.3 Identification, selection and appraisal of studies

Identification
In spite of extensive electronic and hand searches (see methods) it is realised that relevant publications may have been missed. One reason for this is that the South African Journal of Clinical Nutrition, a core journal for publication of nutrition research of South Africa, is not indexed in the biographic databases consulted. Furthermore, because of known database subset inclusion differences, different retrieval results may be obtained were the search to be repeated using semantically equivalent queries (e.g. on Pubmed vs. Ovid-MEDLINE). We are thus not in a position to claim reproducibility in terms of publication identification.

Selection
Selection of studies focused on criteria which ensured that the objectives of this review were met, i.e. to provide *current food* intake information of *poor*, *rural* South Africans.

- "Currency" of intake was assumed if the publication was dated 1994 or more recent, even though a delay in being published is possible. Where date of data collection was specified and referred to obviously outdated information the publication was omitted.
- Preference was given to food information which was presented in a structured form (e.g. a table) with an indication of quantitative ranking.
- Sometimes poverty was assumed, based on reported geographical location.
- Sometimes studies were included based on reported poverty, even though "rural" was vague.

Appraisal
The template created for systematically summarising the individual studies was a purposive attempt to extract information (e.g. sampling, dietary assessment methodology) that could affect validity, keeping in mind the research aims and context.

The identification, selection and appraisal were done by the three people (MF, FW and a study-specific collaborator). It is acknowledged that reproducibility of this process could be questioned, yet authors reviewed each other's work and the manuscript as a whole.

3.4.1.4 Study designs not aimed at describing prevalence

The food intake data reviewed in this report are often extracted from studies with research designs, where sample selection was not aimed at being representative of the study population. Even the descriptive studies often had convenience samples. The external validity (generalisability) of these findings is debatable. Sample size was also a concern in some studies.

3.4.1.5 Compatibility of dietary assessment methodology

Food intake can be assessed on different levels, using different methods and techniques. These cannot necessarily be pooled, as some have inherently different aims and uses (Gibson, 2005). In the studies reviewed a large variety of dietary assessment methods were used, ranging from validated, quantitative methods to tools developed for a particular study, without published evidence of validity and reliability. Qualitative investigations were not included in this report as the findings are not intended for extrapolation. In addition the following was observed:

Ranking and list lengths
Different criteria were used to rank foods. In some studies the ranking was based on the number of times specific foods from a list were consumed (i.e. the food frequency approach). In other cases the percentage of subjects reporting consumption of a food (e.g. in a 24 h recall) determined its rank. Occasionally researchers ranked the "top 20" or "top 10" food based on the "total daily intake" (in gram) by the group of respondents.

Studies not assessing total diet
A substantial number of studies included in this report only focussed on certain food. Consequently the ranked foods do not reflect the "importance" of these foods in the total diet.

Grouping of foods
Across the studies different grouping principles were applied for example during data collection or during data reduction. Sometimes "foods" referred to food groups (e.g. "sweets" or "cereals"), sometimes dishes or composite foods with particular preparation methods or additions were listed (e.g. morogo, vetkoek, atchaar), sometimes very specific forms or even brands of a food were reported (e.g. spider plant, Toppers, brick margarine).

3.4.1.6 Seasonality

Seasonality was rarely reported. In studies specifically focusing on fruit and vegetable intake month(s) of data collection was sometimes mentioned (e.g. Faber et al., 2010). In some studies the effect of seasonal availability was purposefully overcome by repeated measurements over seasons (e.g. Steyn et al., 2001).

3.4.1.7 Limited data available on food procurement

Information on the sources of the foods consumed by rural South Africans is sparse. Some data were found in studies with other research aims, and sometimes the studies only investigated acquisition of certain pre-determined foods.

The only national data, the NFCS-FB, clearly showed that South Africans, including those living in rural areas, *buy* maize, wheat, bread and salt. For these particular components of the diet, which include the staple foods, the source thus seems reasonably evident. Regional and smaller studies tentatively suggest that purchasing may also be the major mode of procurement for other foods. Some studies do point to the presence of home or community gardens, without a guarantee that these are a consistent source of food. Thus in respect of the foods of which intakes appear to be low and which could potentially be home-produced there is limited evidence of its source, including seasonality.

3.4.2 Conclusion

From the results and the critical discussion it is concluded that at this stage there is insufficient evidence to compile a substantiated “basket of foods currently consumed by the rural poor in South Africa”. The preliminary trend that emerged was that current food intake in this group is cereal-based with low intakes of fruit, vegetables and foods of animal origin. In Limpopo Province intakes from green leafy vegetables appear to be higher than the other provinces, and the Western Cape seems to differ from the other provinces in terms of food intake.

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CHAPTER 4

REASONS FOR FOOD INTAKE

Tim Hart

4.1 INTRODUCTION

The previous chapter (Chapter 3) examined food intake and the sources of food consumed by the rural poor. Three striking points emerge from the research examined in that part of the current study. First, the overall majority of South African adults and children consume a diet of low dietary diversity. Local variations are slight. Second, the evidence indicates that most South African households purchase staples such as maize, wheat flour and bread. Regional and micro-studies cautiously suggest that purchasing may also be the primary source of other foodstuffs, the type of which can vary from region to region. Third, while some foods are sourced from the wild, home gardens appear to supplement food intake – especially that of vegetables and legumes. The dietary contribution of such gardens and the variety of produce initially appears dependent on geographical location and associated seasonal variation and natural resource type, quantity and quality. In light of these tentative findings, this chapter examines the variety of reasons for the food choices that are made by poor rural households. Reasons for food intake are taken to reflect the various factors that individually or interactively determine why households and individuals within them consume some foods and not others. In some of the studies reported below this was referred to as reasons for food choices or selection of foods. In this chapter we primarily refer to reasons for food choices but the term is used inclusively and thus it also refers to reasons for food intake and food selection.

An understanding of food choices and the reasons (e.g. cost, availability, taste preference, means of procurement, knowledge, religious prescriptions) for these are important as they are included in the many factors linked to food intake and therefore influence the resultant food and nutrition security of households and individuals. Knowledge of the reasons why certain foods are currently being more or less regularly consumed than others, by members of the rural poor is essential in the process of identifying appropriate interventions aimed at promoting a foods-based approach for addressing malnutrition in this vulnerable group of South Africans.

4.2 METHODS FOR IDENTIFICATION OF STUDIES

This chapter is a desktop review of relevant data sources conducted in two parts. The first component involved the review of a number of recent national surveys to determine if they identified the possible reasons why people consume certain foods and not others. National surveys reviewed included the 1999 National Food Consumption Survey (NFCS), the 2005 National Food Consumption Survey-Fortification Baseline (NFS-FB), the Income and Expenditure Survey (IES) of 2005/2006, and the General Household Survey (GHS) of 2009. The National Agricultural Marketing Council (NAMC) was also approached for information regarding food choices, mainly because the organisation provides annual and quarterly reviews of food price/cost trends. Given the NAMC's specific focus on food price trends, its use of Statistics South Africa datasets, combined with a lack of focus on reasons for food choices and the extent to which food price movements influence food choices, no interviews were conducted beyond the initial contact meeting.

The second component of the study involved a review of literature relating to qualitative and quantitative micro level studies. The methods used to develop and populate a flexible template for summarising the literature relevant to this study are described in detail in Chapter 3. Some of the information relevant to this deliverable was extracted from this template. Colleagues and experts in the food and nutrition security field were also approached for relevant literature and guidance. Other sources included works on the subject that are familiar to the author. The primary literature reviewed are those published since 2000, but where deemed relevant to the discussion other earlier sources are referred to. A thematic analysis of the literature was undertaken to extract the various reasons for food intake. This thematic analysis is reported here in terms of reasons for general factors influencing food choices rather than trying to refer to possible reasons for food choices based on provincial location. However, where provincial indications of choices are possible these are noted.

4.3 REASONS FOR FOOD INTAKE WITHIN A PHYSICAL, ECONOMIC AND SOCIAL ENVIRONMENTAL FRAMEWORK

4.3.1 Overview

A review of the 1999 NFCS, the 2005 NFS-FB, the IES of 2005/2006, the NAMC Annual Food Cost Review of 2009 and the GHS of 2009 indicates that reasons for food intake are not considered in these national surveys. Rather the focus is on food expenditure (NFCS, IES, NAMC), and frequency of consumption of different food groups (IES, NFCS, NFCS-FB-1). The GHS does not consider any of these questions and the relevant questions relate primarily to experiences of hunger/food scarcity. None of the national surveys reviewed consider seasonal differences in food availability and accessibility and how this may impact on food choices. However, some of the national surveys provide a useful indication of food consumption patterns and price/expenditure differences between provinces and also between rural and urban areas (IES, NAMC, NFCS). Generally, all studies conclude that food prices are higher in rural areas. Recent studies by Aliber (2009a, 2009b), which analyse the IES 2005/2006 dataset, indicate that the cost of food in rural areas is generally higher than in urban areas. Aliber (2009a: 11) notes that “for all but the poorest and wealthiest deciles, rural households tend to devote a larger share of total expenditure to food purchases.” This could be evidence of the fact that generally rural households tend to pay higher prices for food and therefore a comparable food basket costs more. However, if we consider the average expenditure per adult equivalent (ADEQ) the picture is somewhat different: “it seems that for each and every decile, rural households spend *less* than their urban counterparts. This appears to relate to the fact that rural households tend to be larger; however, the question remains why rural households actually spend *less*. One possible explanation is own production, which tends to be more common among rural households.” (Aliber 2009b: 399). Although the IES was supposed to collect data about own production to determine the extent of household production of foodstuffs “the amount of own production information captured by the IES is far too little to be credible” (ibid.). As a result the imputed value for the production of own foodstuffs could not be credibly added to the imputed value to household “expenditure” on these items. Aliber suggests that this may account for the gap between the per capita food expenditure for rural and urban households. His analysis also shows that nationally, the poorest income group on average spends 37% of their expenditure on food while the wealthiest income group spends only 7% of their expenditure on food. He also notes that the diets of poorer people are less diverse than those of their wealthier counterparts.

The review of literature relating to qualitative and quantitative micro level studies identified only two studies that focused particularly on current food practices and the reasons for contemporary food intake among households in South Africa. The study by Viljoen et al. (2005) focused on the factors that influence the transition from traditional to contemporary food behaviour/culture and provides an illuminating perspective on the various relevant themes that influence household and individual food choices. This study was less concerned with representativeness and more concerned with the relevancy of the sample to the chosen topic. Therefore the study used a very small sample of respondents (35 adult females and 8 schoolgirls between 16 and 18 years of age). The study by Love et al. (2001) focused on the possible constraints to introducing preliminary Food Based Dietary Guidelines (FBDGs), from which a number of factors influencing food intake were drawn. The study sampled 137 women in predominantly urban areas of the Western Cape and KwaZulu-Natal and is thus not representative of the national population or rural areas in particular. Most of the other studies are fragmentary and provide sporadic pieces of information that allow some limited interpretation as to the reasons for contemporary food choices at specific sites around the country.

The studies reviewed are often unclear as to how poor people are defined in a particular study (what indicators used, e.g. income poverty, education poverty, etc.). Therefore, it was impossible to consider the different levels of poverty and associated food consumption patterns at different levels. Many studies indicate a sample of poor households/individuals but do not define poverty using any comparative indicator nor are there seemingly any studies which specifically focus on food intake variations at different levels of poverty. Aliber's discussion of the 2005/2006 IES, noted above, sheds some light on food expenditure patterns in terms of different deciles, and further reading of this article is recommended.

Despite its focus on a single village in the North West Province, the study by Viljoen et al. (2005) provides a useful framework in which to consider the factors influencing contemporary food intake. The relevant themes are:

- Physical environment (Determining Availability and Accessibility)
- Economic and political environment (Determining Affordability)
- Socio-cultural environment (Determining Acceptance)
- Individual environment (Determining Individual Choices)

Furthermore, the study is considered extremely helpful as it attempts to compare traditional food intake with current food intake and considers some historical and current factors that brought about the observed changes in dietary intake, as identified by participants. Some gaps do exist in this study, for example, the work on the physical environment does not look at health, sanitation and education infrastructure, while the work on the economic and political environment does not consider the role of social grants and the impact of regularly fluctuating food prices to any significant degree.

A number of the studies reviewed showed a growing concern in respect to the affect of HIV/AIDS on household food security and how it determines the availability and access to food. Consequently, it is deemed important to consider how HIV/AIDS influences peoples' food choices, especially as the impact of the disease is felt across a number of the environments mentioned above, primarily at the household and individual level as an economic shock, and thus influences reasons for food intake. South Africa is reported to have the highest number of HIV-infected persons in the world, with about 5.5 million people living with HIV (UNAIDS and WHO, 2007). Within South Africa, Mpumalanga has the highest prevalence of HIV, followed by KwaZulu-Natal (Shisana et al., 2008).

The onset of HIV/AIDS in Southern Africa is exacerbating the food insecurity and malnutrition situation, which was previously and almost exclusively attributed to droughts, famines, wars and weak governance of national food security and relief strategies. HIV/AIDS affects the economically active and able-bodied members of the population in the region, reducing household resilience and ability to recover from shocks and stressors (de Waal and Whiteside, 2003; Drimie and Casale, 2009). De Waal and Whiteside (2003) identify four new factors, attributed to the HIV/AIDS prevalence in Southern Africa, which have created a new category of highly vulnerable households, negatively affecting household food security and thereby limiting food choices:

- Adult morbidity and mortality result in household labour shortages and the rise in the number of household dependents, as orphans must now be cared for by other households. More income and food is required but less able-bodied labour is available to secure these.
- Adult mortality results in the loss of assets and skills. While assets are often rapidly sold to cover immediate unforeseen expenses due to loss of income and health care costs, livelihood skills are often not transferred thereby increasing hunger and preventing strategic livelihood planning.
- The burden of care is large for adults afflicted with HIV/AIDS and also for children orphaned by AIDS, involving great cost and diversion of labour.
- Severe and negative interactions exist between malnutrition and HIV/AIDS. Undernourished individuals are more susceptible to HIV infection. People living with HIV have higher nutritional requirements and good nutrition is essential for effective antiretroviral treatment. Consequently, malnourished afflicted persons are likely to experience a rapid progression from HIV to AIDS.

The results section now details the various factors that influence contemporary food choices based on the information extracted from the studies reviewed. An attempt is made to follow the four themes proposed by Viljoen et al. (2005). The significance of HIV/AIDS on food choices is discussed as an addition to the Economic and Political Environment in the form of disease and death influencing food choices. The limited evidence obtained from the literature reviewed seems to emphasise that, for the time being, this is where HIV/AIDS has it most significant and immediate impact on food choices. However, there are effects on other environments that are related to HIV/AIDS and where possible these are noted in the report.

4.3.2 Physical environment

The physical environment refers to the natural environment and infrastructure (manmade environment). In this section the influence of natural resources, seasonal variation and infrastructure, such as shops, roads and technology (appliances) are considered in terms of how they influence access and availability to food and thus influence food intake. However, it should be noted that geographical location has a significant effect on the physical environment and determines the type of resources available as part of the physical environment. Furthermore, a healthy environment (the availability of safe water, sanitation, refrigeration, nutrition education and health care services) also influences the ability of households and individuals to utilise food effectively and to derive the optimal nutritional benefits from food. However, none of the studies touch on this specifically, although Viljoen et al. (2005) refer to the presence of water and refrigeration.

4.3.2.1 Natural resources

The availability and quality of natural resources to a large extent determines the types of food crops that can be produced or cultivated in a particular area. The production of food, irrespective of the scale, is dependent on climate, water and soil fertility. Risky and constrained crop production of poor rural households is a result of South Africa’s climate, the relative scarcity of water in most areas and the low potential of arable land available to subsistence producers (Ortmann and Machethe, 2003). Current residence in marginal areas with poor natural resources was directly influenced by the 1913

Native Land Act and various Apartheid era policies and strategies. Primarily, people were relocated to small areas that became overpopulated and this put increased pressure on the natural resource base. Attempts to improve the natural resource base (so-called Betterment Schemes) were inappropriate and often resulted in further deterioration. Viljoen et al. (2005) report low incidences of agricultural activity for households in a village in the North West Province due to water scarcity, poor soils and availability of land. In Limpopo Province, Hart (2011) notes that water scarcity and poor soils restrict village residents' ability to cultivate extension promoted exotic vegetables, while the production of traditional crops (maize, groundnuts, cowpeas, and some African Leafy Vegetables), especially hardy varieties, is widespread.

While many of the former homelands are situated in the eastern part of South Africa, which obtains significantly better rainfall than the western part, the steep terrain reduces the amount of arable land available and this is further exacerbated by the increases in soil erosion brought about by this terrain (Feynes and Meyer, 2003). Although the veldt grazing in these areas is of high potential, current stocking practices exceed the carrying capacity of the land in most of these areas. Subsequent overgrazing has severely affected the quality of arable land and in many areas it is no longer suitable for crop production (ibid.). Many rural households rely on rainfall for agricultural production and do so in environments where the soil quality is poor. Despite this more than 2.5 million black households in South Africa are engaged in some form of agricultural activity, with the majority doing so to supplement the household food supply (Aliber and Hart, 2009). Most studies focusing on food production by rural households note the constraints they face in terms of suitable natural resources and the deterioration of these (Kirsten et al., 1998; Hendriks, 2003; Groenewald and Nieuwoudt, 2003; Hart and Vorster, 2007; Aliber and Hart, 2009; Hart, 2011). Unfortunately many formal analyses of smallholder and household food production that focus on yields, overlook the value of the crops consumed (often on a daily basis once they start to ripen) prior to the main harvest (McAllister, 2001) and the amounts and value of the minor crops (such as cowpeas and pumpkin) intermixed with the major staple crop (such as maize) (High and Shackleton, 2001; McAllister, 2001). The consequence is that such formal analyses tend to underplay the role of rural household agriculture and its contribution to food security.

In recent years, a number of studies have drawn attention to another dimension of the role of natural resources in household food supply: the fact that the harvesting of products from the wild, for food and other livelihood purposes (for example, housing, fencing, energy, medicine) is a significant resource for rural communities and households (Shackleton, Shackleton and Cousins, 2000a and 2000b; Shackleton et al., 2000; High and Shackleton, 2000; McAllister, 2001; Shackleton et al., 2001; Shackleton et al., 2002; Dovie et al., 2003; Twine et al., 2005; Hunter et al., 2007; McGarry, 2007; Kaschula, 2008; McGarry and Shackleton, 2009; Cocks et al., 2008). In rural areas gathering of food from the wild is more prevalent than in urban areas, as the availability of uncultivated areas and fields is less likely in urban areas – even within informal settlements (Kruger et al., 2008). The use of wild resources for food is considered culturally acceptable among rural communities in South Africa (Matla, 2007 – cited in Kruger et al., 2008). However, such practices are now often a safety net and their intensity increases in times of misfortune or increased poverty, indicating a coping response to livelihood shocks.

Shackleton et al. (2000) identify a greater reliance on wild foods during drought periods because arable exotic crop production has either failed or decreased substantially. Kruger et al. (2008) report that the poverty level of farm worker households in the Free State necessitated fairly regular harvesting of plants and fish when seasonally available, in order to diversify their meals throughout the year. Twine et al. (2005) and Hunter et al. (2007) report that in times of unemployment, or when the breadwinner is deceased (particularly a male breadwinner), households tend to increase their reliance on resources harvested in the wild, either directly as food or to sell products to generate and income to purchase food (see also McGarry and Shackleton, 2009). Wild foods may substitute for foods that were previously purchased (Hunter et al., 2007).

Foods collected from the wild tend to include edible herbs/African leafy vegetables (ALVs), wild fruits, and various mammal and insect species for consumption. Insect species include termites, flying ants, locusts/grasshoppers and mopani worms (Twine et al., 2003; Hart and Vorster, 2007; Hunter et al., 2007). Mammal species include buck, warthogs/wild pigs, hares/rabbits, birds and mice (Twine et al., 2003; Hart and Vorster, 2007; Hunter et al., 2007; McGarry, 2008, McGarry and Shackleton, 2009).

Dovie et al. (2003) found that more than 90% of households harvested edible herbs/ALVs, with women being the main harvesters, harvesting most ALVs in farmers' fields and disturbed sites around the homestead. A similar pattern is noted by Hart and Vorster (2007) and Hart (2011) in a study of two settlements in the Mopani District of Limpopo Province. Hart and Vorster (2007) reported that some households actually cultivate and consume certain species of ALVs, because these grow better than many exotic crops in these areas. Given that most ALVs are not commercially available commodity crops, households that cultivate them develop their own seed saving and cropping systems (Hart and Vorster, 2007; van Averbeke, 2008, WRC TT 344/08).

High and Shackleton's (2000) survey of a village in the Bushbuckridge area of Mpumalanga, highlights the direct (sales) and indirect (savings by not having to buy) financial implications for rural households when wild plants are harvested and consumed (see Twine et al., 2003 for a list of similar studies conducted in South Africa between 1999 and 2003). High and Shackleton (2000) report that the average value of wild ALVs per home garden was R626 (SD R516). The total mean value of the morogo consumed in this village was R517 (SD R492). The total mean value of morogo sold per household was R109 (SD R256). The per hectare value of between R990 and R1580 for wild plants compared favourably with the domestic vegetable plant value of R2200-R3580 per hectare per year.

A study conducted a few years later, highlights the differences between the uses of edible herbs in two villages in Limpopo Province and one village in KwaZulu-Natal (Shackleton et al., 2002). Differences in use and consumption patterns were ascribed to the types of wild food available in the villages. The village that consumed the lowest amount of edible herbs/ALVs per person also had access to fish and ilala palm, products that are not available in the other two villages. This illustrates that differences in consumption of ALVs and other products from the wild depend on what species are locally available (dependent on vegetation type and natural environment – see Cocks et al., 2008) and what alternative foods exist in different areas. Although focusing on the harvesting of natural resources for a variety of purposes, not only species consumed as food, the study by Cocks et al. (2008) found the geographical location of different villages to be more significant than inter-household variables such as gender and wealth with regard to the number of species of plants harvested, the particular use they were put to, and the quantities used. Household wealth did not significantly influence the consumption of wild fruit and African leafy vegetables (ALVs) (ibid. 203-204).

Labadarios et al. (1999) found that ALVs were the fourth most frequently consumed food for children between 1 and 9 years in the Limpopo province, while in KwaZulu-Natal they were only the twentieth most regularly consumed food by children within the same age group. Faber et al. (2010) suggest that the variation in consumption patterns is determined by taste preferences and availability of different species in different geographical locations. They also suggest that greater consumption may reflect a higher level of poverty at particular sites. Vorster et al. (2008) found similar geographical diversity in availability across three sites in Limpopo, Mpumalanga and KwaZulu-Natal, with poor rainfall and soil conditions restricting the availability and use of ALVs at the Mpumalanga site. McGarry and Shackleton (2009) found that children residing in coastal villages in the Eastern Cape reported consuming meat more regularly than those residing in inland villages, because children near the coast tended to harvest meat more regularly from the wild than those living inland.

The importance of wild foods to rural diets cannot be ignored. The National Food Consumption Survey (NFCS) of 1999 illustrated that green leafy vegetables (ALVs plus spinach) were the fourth most regularly consumed food item for children aged 1-9 years in Limpopo province (Labadarios et al., 1999). Hart (2011) reports that in Mopani District 95% of surveyed households deemed ALV's important to their diet and food security, with all respondents to the survey having consumed them during the past year. Significance was attached to the fact that some ALVs are easily dried and stored for consumption during the winter months when they are not freshly available. Furthermore, 95% of the households had these plants in their homestead gardens during spring and early summer, where they were actively cultivated or nurtured. Similar trends and high consumption patterns are reported by Dovie et al. (2003), Twine et al. (2003) and Hunter et al. (2007). In their Mpumalanga study Hunter et al. (2007) report that 90% of households consumed Jute or Jew's Mallow, the favourite ALV at this site, which was often nurtured in home gardens. Of the households surveyed 67% acknowledged harvesting wild herbs, 27% harvested wild fruits, including *marula*, and 20% of households consumed insects to supplement their diet. The study of six villages in the Eastern Cape, by Cocks et al. (2008), reports that 49% of households gathered wild herbs/ALVs to consume as a relish.

In a more recent study of six different villages in the Eastern Cape, McGarry and Shackleton (2009) note that children's dietary diversity increased by 13% when food intake is supplemented with wild foods. In this particular study 62% of children were supplementing their food intake in this manner and 30% had over half their diet supplemented with wild foods. The most common reasons for gathering food from the wild were enjoying the taste and to satisfy feelings of hunger. The latter is important as some children reported preparing and consuming their wild foods in the wild so that parents would not ration their domestic meal for the day (ibid.: 30). The implication is that while children may gather wild foods for the household, they may also do this independently, consuming 'their harvest' before returning home to ensure that they do not go hungry and are not denied their evening meal.

4.3.2.2 Seasonal variation

Virtually none of the studies reviewed explicitly consider seasonality as an important area of analysis in the food security equation in South Africa. Besides the study by Kruger et al. (2008), which focused on seasonal food coping strategies, some of the other studies mention seasonality as a contributing factor to food availability and access, without delving deeper in seasonal food consumption patterns and possible differences that might be experienced across seasons. In this regard, most studies merely note what crops are produced during the summer or winter rainfall season, depending on the study site's location in summer or winter rainfall areas and access to irrigation.

In their study of two rural settlements in Limpopo Province, Hart and Vorster (2007) report that because access to water is a major problem, most crops are cultivated during the summer rainfall season and that only 6% of households with standpipes in their homestead actively produce winter crops. In summer, production mainly consists of maize and traditional food crops (particularly ALVs, ground nuts, cowpeas and cucurbits, as these were considered suitable to the local climatic and environmental conditions). Most households dry and store maize and some ALVs for consumption during the winter months and many consider this an important strategy to ensure food availability during winter. Greater employment opportunities on commercial citrus farms in the area during winter afforded a significant number of households (20%) an income during this period, which enabled them to purchase other food stuffs (e.g. chicken, exotic vegetables, canned fish) that are not produced by households (Hart 2011). Viljoen et al. (2005) report similar findings for the village of Mmotla in the North-West Province, in that a lack of water for agricultural purposes prevailed and only when rainfall was good did people harvest ALVs from their gardens and veldt, some of which were dried and stored for consumption during the winter months. In his study of irrigation schemes in Vhembe district, Limpopo province, van Averbeke (2008, WRC TT 344/08) notes that during winter the production of winter crops featured prominently, as a result of the availability of irrigation at the irrigation schemes or in household gardens.

The surveys conducted by Love et al. (2001) and Temple and Steyn (2009) found that seasonality not only affects the availability of certain foodstuffs but also affects the prices of foods. At the beginning and after the season, the prices are higher than during the peak of the season. In her study in Venda, Tshihwanambi (2007: 68) notes that seasonal availability was a significant factor with regard to food consumption. This was especially the case with regard to what fruit was available in the home gardens. She also notes that the consumption of indigenous fruit from the wild was high during the summer rainfall season when these fruits were available and collected and consumed by children.

The study undertaken by Kruger et al. (2008) on the food coping strategies of a farm worker community in the Fouriesburg area of the Free State Province is particularly illuminating with regard how seasons influence food coping strategies and thus seasonal intake. By dividing the long summer period into two seasons, Kruger et al. (2008) conducted their study across five seasonal periods (early summer, late summer, autumn, winter and spring). They noted that late summer and winter appeared to be the time of greater food insecurity (scarcity). The four most commonly employed food coping strategies during different seasons are as follows (ibid. 6):

- Across all five seasons the two most common strategies were consuming less preferred or cheaper food and harvesting wild food;
- During early summer and again in winter households tended to consume seed stock as food availability was scarce;
- In winter and late summer food portion sizes were reduced;
- In late summer and spring, when food crops cannot be harvested and wild leafy vegetables are scarce, food was bought on credit.

Kruger et al. (2008) also attempted to determine the severity of each coping strategy for this particular community. Eating less preferred and cheaper food was considered to be the least severe food coping strategy and is the simplest food coping action that a household can adopt. Meat was seldom purchased, so the strategy involved buying alternative sources of protein: chicken feet to make a sauce, soya mince to make gravy and buying milk cheaply on the farm. These food stuffs were all consumed with maize porridge, which provided energy and satiety value and a proportion of which was provided as part of the farm workers' wages. Harvesting in the wild was considered a severe coping strategy, although it was used by households to provide food throughout most of the year. Severity is probably a result of the fact that the starch based meals of low-income households are generally monotonous and thus the regular activity of harvesting in the wild is to add variety to the maize porridge by making a relish from the ALVs and other foods harvested. Some harvested wild foods were dried and stored for consumption at different times of the year (ALVs and fish). The reduction of portion sizes was also considered severe and indicated that although food was still available during the seasons when this occurred, availability was reduced. Buying on credit and consumption of seed stock were considered very severe coping strategies. Existing low-incomes limit households' ability to meet credit repayments. They are fearful of this and only buy on credit when they know they will soon get money to pay back the loan and that food will soon become available. Consequently, this strategy is implemented in the lean period immediately prior to harvest time. Consumption of seed stock is a result of the lack of available food in the period after the harvest has been consumed and when the next crop has been planted.

4.3.2.3 The physical environment and infrastructure

Viljoen et al. (2005) note that residents of Mmotla were not in a position to cultivate their own food crops due to the inadequacies of the local natural environment. This led them to adapt their diets with respect to what was available at local shops or in the nearby towns. Gradually they included modern food items as these were readily available in their local shops while most traditional foods were scarce or expensive. The studies by Viljoen et al. (2005), Hart and Vorster (2007) and Kruger et al. (2008) also draw to our attention that, at least in these three different study sites, relishes that accompanied maize porridge were often watery (made from a few vegetables and small amounts of cheaper offal meat products) and included various premixed seasonings, which were readily available in the local spaza shops and general dealers.

Urban areas generally have access to a greater variety of food stuffs due to the high concentration of different types of food retailers in these areas. In rural areas variety is generally less, even within supermarket chains in rural areas variety is less than in urban areas, and many rural consumers are heavily reliant on general dealers, spaza shops and what they can purchase from local informal markets, hawkers and producers (Hart and Vorster, 2007; van Averbeke, 2008, WRC TT 344/08). In a study of rural towns in the Western Cape, Temple et al. (2011) confirm that in smaller rural towns the local food store is small and offers only a limited number of healthy foods. While the same study reported that larger rural towns usually had a supermarket, and that most people travelled to these towns weekly or monthly (c.f. Lemke et al., 2009), the authors suggest that the selection of healthy foods (in many cases perishable foods) would require strong motivation. Such a selection would mean purchasing greater quantities, transporting them over long distances, usually by means of public transport and the ability to store such foods until the next visit. The household would need to have suitable storage facilities to ensure that the quality of the healthier food is maintained.

Only the study by Viljoen et al. (2005) highlights the fact that while most of the households in Mmotla village access electricity and own electric stoves, only the minority of residents owned or had access to refrigerators, the implication being that most residents would store some of their perishable foods (including meat) with relatives or neighbours who owned refrigerators or deep freezers. In the study by Hart and Vorster (2007) only 3% of the households in two Limpopo settlements had access to electricity. While some gas/paraffin refrigerators were observed none of these were being used. This indicates that in these two settlements most of the households did not have refrigerators in which to store perishable foods. As a result most households bought small quantities of perishable foods which they ate quite soon and dried and stored other foods such as ALV's, maize and cucurbits for consumption at a later time. Storage of perishable foods appears to be a problem and thus requires regular purchase from local shops, if such foods are locally available.

The availability of electricity and water also has implications for how food is prepared. Viljoen et al. (2005) note that in households with electricity, meat was fried on the stove or grilled in the oven, while vegetables were sometimes fried. The availability of energy (electricity, fuelwood and paraffin) and water were also cited as a constraint in the preparation of some foods, especially those that required more cooking time, such as legumes (Love et al., 2001).

Access to water is particularly relevant. Despite the importance of a healthy environment, access to quality potable water and sanitation and the presence of health services, to food security and malnutrition none of the reviewed studies consider these factors in any detail. The ability to use food in a healthy fashion is determined by, amongst other factors such as education, a healthy environment and this is noted as one of the four elements of food security (utilisation of food) in the 1996 FAO definition (FAO 2001, 2006). The UNICEF Malnutrition Framework considers a healthy environment to be a decisive factor in determining nutrition security (Levitt et al., 2009).

Despite natural resources dictating what crops could be produced and consumed, villagers in Limpopo also noted that the seeds of some of the favoured traditional food crops were difficult to obtain locally (Hart and Vorster 2007). Despite some local shops and the nearby Cooperative selling seeds, these were for exotic crops and not for traditional foods (Hart 2011). As a result some local women tried to harvest their own seeds for some crops and exchanged these with other farmers. However, women did not consider this to be very successful as seed was often lost due to storage problems. Van Averbeke (2008, WRC TT 344/08) notes the practice of seed harvesting and storage for nightshade in Vhembe, as a result of the seed being commercially unavailable.

4.3.3 Economic and political environment

The economic environment refers to the employment opportunities that are available and how these impact on food choices, especially with regard to the affordability of food. The political environment relates to how certain government policies such as agricultural assistance, school feeding schemes and nutritional programmes may impact on reasons for food intake. Also noted here are local political arrangements of land tenure and thus access to natural resources on which to produce or harvest food from the wild.

4.3.3.1 Employment opportunities

In contrast to urban areas, food prices in rural areas generally tend to be higher (Aliber, 2009b) and wages lower, so the type of food purchased depends largely on income and the type of food available in the rural shops. The regularity of which food products are purchased largely depends on income quantity and frequency. Viljoen et al. (2005) report that labourers in the North West usually got paid on Fridays and this resulted in households eating meat and other relatively expensive foods on the weekend. In fact they report the most varied meals occurring on weekends and which differed from the simpler and cheaper meals consumed during weekdays.

McGarry and Shackleton (2009) found that children residing in inland villages in the Eastern Cape generally only consumed domestic meat once a month, at the time of the monthly pension payout. In Limpopo province Hart and Vorster (2007) report that the monthly pensions days were accompanied by the purchasing of a wider variety of foodstuffs and often hawkers came to the villages on these days to sell food a variety of foods, including live chickens. Due to seasonal employment during the winter months some residents in these settlements noted that they ate better as they had money and were paid weekly during the late autumn to mid-winter period (Hart and Vorster, 2007). The poorer households would tend to consume more dried African leafy vegetables and other stored foods if they did not have a household member who was employed during this period.

Temple et al. (2011) indicate that healthier foods typically cost between 10% and 60% more than those foods generally consumed as part of the typical South African diet. Changing from the typical South African diet to a healthier option is likely to result in higher food expenditure (Temple et al., 2011), which poor rural households may be unable to afford. Temple et al. (2011) suggest that the high cost of a healthy diet may be offset by own production in home gardens or through purchasing healthy foods direct from farmers. However, this suggestion at least presupposes that people are located in an area with a suitable climate, adequate access to water, soil, land and other resources of sufficient quality to produce the healthier foods. Focus group discussions undertaken by Kruger et al. (2008), within a farm worker community in the Free State, show that the farm workers could buy subsidised food such as fresh milk, meat, maize meal, eggs, poultry or vegetables, depending on the type of farming in which the farm was engaged.

4.3.3.2 Government and other support services

With regard to availability and accessibility of food it is worth considering the influence of various government and other support services, notably food gardens, soup/food kitchens and school feeding programmes that are found in some rural communities and which target the very poor and vulnerable. Few studies take cognisance of the impact that these have on food consumption patterns. Hart (2009) reports that the Department of Health has a number of programmes that focuses on food security to the extent that they provide people either with meals or with food which they prepare at home. These programmes include the National School Nutrition Programme (NSNP), the Clinic Garden Project (CLG) and the Protein Energy Malnutrition Scheme (PEM). Since 2009 the Department of Basic Education has administered the NSNP.

The NSNP involves providing targeted schools with food and agricultural skills, inputs and equipment so that they can produce crops to feed learners. In her study in Venda, Tshihwanambi (2007: 68) found that school feeding programmes provided a diverse supply of fruits to school-going children. McGarry and Shackleton’s (2009) study of HIV/AIDS afflicted and non-afflicted children between the ages 8 and 18 in the Eastern Cape suggests that school attendance has some role to play in food intake. Non-school attending children had a 13% lower domestic Individual Dietary Diversity Index (IDDI) score than school attending children. This measurement involved a simple 24-hour recall of the child’s food intake and used the IDDI methodology, as reported by Ruel (2002) and Swindle and Bilinsky (2005), to assess the variety of foods needed for adequate nutrition by each child. McGarry and Shackleton (ibid. 33) offer two possible explanations for this difference in IDDI score. Firstly, it could be due to the overall extreme poverty of the households that could not afford to send their children to school, indicating that extreme poverty generally made food scarce. Secondly, it could be that the reduced diet was a result of their omission from school feeding schemes. Access to schooling also affected diet in that children who consumed the highest proportions of wild foods were those children who did not attend school.

The CLG provides the members of food gardens, located at public health facilities, with the resources to produce food for their households. Membership includes individuals and families affected by HIV and AIDS and tuberculosis, and also households with children admitted into the PEM. The PEM provides nutrient-dense meals to clients who have been identified as malnourished (Hart 2009).

The various provincial Departments of Agriculture also support community gardens across the country, although Aliber and Hart (2009) and Hart (2011) note that often project conceptualization and the subsequent support can prove incompatible with local circumstances, particularly the environment and the local socioeconomic circumstances of the beneficiaries. As a means of providing the households involved with regular food such projects are perhaps questionable, but when they do function they tend to place their emphasis on exotic crops, the availability of which might be a further factor that determines local households' food selection and intake.

Churches and non-profit organisations also provide food in the form of meals to vulnerable people and in most cases religious denomination or membership are irrelevant to accessing this support. However, use of these services depends predominantly on their existence in a particular area. None of the studies reviewed reported on this type of food programme.

4.3.3.3 Local tenure arrangements

Access to land is important to both production of food crops and harvesting in the wild. Different tenure arrangements within different villages, often under the authority of traditional leaders, reflect the different types of access to natural resources (Cocks et al., 2008) and this in turn determines the amount of food and other crops that rural households can produce or harvest from the wild, thus affecting intake. Ainslie (1999) reports that in the Eastern Cape, open access conditions prevail with regard to communal lands but while each village has a committee of elected members that consider rights of access and land allocation, these committees are largely ineffective.

Gender also plays a role with regard to access to land as in many cases females have access to land through their husbands or male household members. Hart and Vorster (2007) noted that larger parcels of land were usually accessed by males for cash cropping, while females largely produced food crops in home gardens. The village headman or nduna is responsible for allocating land for cultivation and residence. In their Limpopo study Hart and Vorster (2007) report that the availability of land for cultivation outside of the household garden was severely constrained and few households had access to such land. The same study notes that most households produced traditional food crops in household gardens during the summer rainfall period.

HIV and AIDS afflicted individuals and households may be particularly careful to avoid any actions that are seen as anti-social, such as overharvesting of wild food and other resources from lands subject to communal tenure (Kaschula, 2008).

4.3.3.4 Disease and death

Death and disease result in an economic shock for the household and thus negatively affect the economic environment of the household before. Economic factors (available financial resources and assets, labour ability, utilisation of existing assets and household size) will be immediately affected upon affliction with a debilitating disease or death of a household member. Drimie (2003) and Hunter et al. (2007) find that mortality-affected households (AIDS-proxy households) reduced their cultivation of crops because of the reduction in available labour and assets in these households. Furthermore, Drimie (2003) notes that reduced labour, through death, also reduces the ability to adequately care for the land that remains cultivated. However, he does suggest that reduced land use and care may result in the increased availability of wild foods in such lands, thereby providing a nearby source of wild foods for the household and individual. Consequently, close presence of wild foods combined with the shortage of labour and assets will encourage the consumption of wild vegetables and herbs.

Following the mortality of an adult household member, Hunter et al. (2007) report that overtime, foods collected from the wild generally replaced those that previously produced or purchased. Where a household had previously relied predominantly on purchased foods, mortality of the main breadwinner increases the likelihood that previously purchased food is replaced through increased reliance on production and gathering activities. However, this pattern would occur overtime and was not an immediate response to adult mortality. Resorting to own production (notably maize) is more likely for poorer households that recently experienced a death. The death of an adult male is more likely to result in the loss of wage income than that of a female. Households that experienced adult male mortality were more likely to turn to harvesting in the wild for food, than those experiencing the death of an adult female. Kaschula (2008) reasons that this is largely because wild foods are normally collected by women and children, and increased consumption of such foods, in households that have experienced male-mortality, results from a higher availability of adult female and child labour. Similarly, fostering paternal orphans may also lead to the relative increase in the availability of child labour and thus an increase in wild food harvesting activities (ibid.).

However, increased dependence on food from the wild is not to be considered a short-term coping strategy brought about by HIV/AIDS. Both Hunter et al. (2007) and Kruger et al. (2008) found that food security was generally maintained by harvesting from the wild. Other studies cited in this report concur with this idea that harvesting from the wild is a fairly common practice for poor households (Kruger et al., 2008), irrespective of whether or not they are afflicted by death and disease. However, the findings of Hunter et al. (2007) suggest that natural resources help to mitigate the shock experienced when a household is affected by HIV/AIDS, as mortality-affected households indicate increased dietary dependence on edible wild plants over the long-term. The study in the Eastern Cape by McGarry (2007) and McGarry and Shackleton (2009) reveals that harvesting edible foods from the wild may be fundamental to the food coping strategies of orphans and vulnerable children. Therefore, children's labour is important in terms of the contribution they make to natural resource collection and food coping strategies. Children from AIDS-proxy households tend to eat meat far less often than children coming from non-affected households suggesting that AIDS-afflicted households face significant constraints with regard to food choices.

The study by Kaschula (2008) found that mortality-affected (AIDS-proxy) households are much more food insecure than non-mortality affected households. Furthermore, she found that households fostering orphans were poorer and experienced higher levels of food insecurity. She proposes that households that generally use wild foods may be more resilient than those that don't, perhaps because income was never a major determinant for food procurement and hence the loss of income is not as devastating as it is for those households who were heavily dependent on income for purchasing food.

4.3.4 Socio-cultural environment

According to Jerome et al. (1980) the socio-cultural environment refers to the cultural and ideological understandings of the role of food in health, religious beliefs involving food, specific foods and restrictions (taboos) and the use of food in social interaction (gift giving, rituals, ceremonies). Cultural norms determine what is considered edible, how it is acquired and prepared, how meals are conceptualised, the content of particular meals, patterns, frequency and times, and also meal etiquette, such as who eats what (Asp 1999 – cited in Tshihwanambi 2007). Viljoen et al. (2005) suggest that urbanisation, ethnic identity/tradition, religion and acculturation influence reasons for food intake. Based on the review of literature some other factors are also included which are considered part of the socio-cultural environment.

4.3.4.1 Urbanisation and migration

Urbanisation and new socioeconomic pressures on both rural and urban families, as well as lifestyle changes among the urban and rural poor, force families to turn to high-carbohydrate, high-fat fast foods/snacks in order to meet their daily food requirements (Kota, 2006). People have become less-reliant on own production (Aliber and Hart, 2009) and thus less self-reliant, depending on large industries for their food (Kota, 2006). With increasing urbanisation, the trend in dietary simplification continues. More and more African women find employment outside the home, often travelling long distances to and from work. Consequently, they have less time available to prepare family meals and so turn to high energy dense but low nutritional value street foods or easy-to-prepare cereals, such as rice, wheat and maize (Frison et al., 2005).

Some rural households report relying on the food supplied to them by family members living in urban areas (Kaschula 2008). Viljoen et al. (2005) note that food preparation and consumption habits learned while working in urban areas are often disseminated within households.

4.3.4.2 Tradition, culture and religion

In their study, Love et al. (2001: 18) identify food choices as partly being a reflection of cultural preferences. Black participants are reported to eat and enjoy *maas* (soured cultured milk), and Love et al. (2001) conclude that this was largely because of their cultural eating habits. All black South Africans (urban and non-urban alike) interviewed in the Love et al. (2001: 15) study reported that they made starchy foods, such as maize porridge, potatoes, rice and bread, an essential part of most meals “as a result of traditional/habitual food consumption patterns.”

White participants in the Love et al. (2001) study indicated consuming a wide variety of fruit and vegetables, indicating better affordability and accessibility to these food stuffs. Black respondents indicated that the consumption of fruit and vegetables was determined by affordability. Legumes were often consumed as a protein replacement, substituting for meat, and to extend the meal portion sizes due to their relative cheapness (Love et al., 2001). Legumes consumed include a variety of dry beans, canned baked beans, lentils or split peas, soya mince, groundnuts, bambara nuts, and cow peas (Love et al., 2001; Hart and Vorster, 2007; Kruger et al., 2008). In the Love et al. (2001) study, Indian participants reported consuming the greatest variety of legumes, reflecting the cultural eating habits of this group. Indians acknowledged both sexes liking legumes, while white participants reported that often male adults refused to eat them, preferring meat. Black participants largely included legumes into their diet because of their affordability relative to other foods (Love et al., 2001), and the ability to cultivate them more easily than other crops in semi-arid areas (Hart and Vorster 2007).

The influence of religion in dietary habits is apparent from some of the South African studies reviewed. Tshihwanambi (2007) found that the Zion Christian Church in Venda proscribed certain food stuffs to be avoided by members. Love et al. (2001: 16) found that Indians are less likely to eat beef due to cultural and religious beliefs. While their study did not report this there are in fact differences in religious affiliation within the Indian group in South Africa. Although Hindus often do not eat any meat, Christian and Islamic Indians eat other meats and not all are vegetarians.

Viljoen et al. (2005) report that some Christian denominations prohibited their members from eating any food on a Sunday morning before taking Holy Communion, indicating the importance of abstinence before certain rituals amongst some denominations. The same study and that of Kota (2006) noted that some churches restricted or prohibited the use and preparation of fermented dishes and beverages – both alcoholic and non-alcoholic. While none of the studies reviewed, provided a lot of information on the influence of religion on consumption patterns, what is important, for the purposes of the current study, is an awareness that different religions proscribe and prescribe certain food stuffs and that these need to be considered in future studies.

In a comprehensive study of livestock production in the Eastern Cape Ainslie (2002a) and Kepe (2002) draw our attention to the wider social benefits that are afforded to the rural poor by the variety and number of livestock owned by their kinfolk and *Isithebe* (neighbourhood grouping). An earlier study by McAllister (2001) draws our attention to the importance of livestock products, such as meat and milk, along with samp, bread, tea and a fermented maize meal beverage (*marhewu*) that are distributed to agricultural work parties in return for labour assistance. Regularity of access to red meat and other diverse foodstuffs by poor rural residents may be determined by the redistributive aspects of cultural ritual events and ceremonies (for example, funerals, weddings, initiation ceremonies, and membership of working parties) (see Ainslie, 2002a and Kepe, 2002). Ainslie suggests that attendance of various ritual events and ceremonies, at which meat and other food stuffs are freely provided, might be a conscious element of the food security strategy of poor rural people, as the events are often attended by all local inhabitants (ibid.: 9). McAllister (2001: 45) reports that major and minor ancestral rituals provide rural inhabitants in Shixini (a ward in the former Transkei homeland) with 'occasional large supplies of high quality protein.'

The consumption of livestock through ritual events is possibly a significant contributor to food and nutrition security in some former homelands. Tapson (1982) reports that in 1981 that 79 771 animals in the former Transkei had been slaughtered for home use. Home use often refers to use in ritual purposes and includes livestock sold to other households for ritual purposes (Ainslie, 2002a: 5), particularly if they do not possess the requisite animal (Ainslie, 2002b: 112). Ainslie (2002a) reports that his own studies indicate that in 1997 the number of livestock slaughtered in the former Transkei amounted to 120 000 animals. Certain rituals require the slaughter and consumption of specific animal types and sizes thus varying the type of meat available as part of the traditional social calendar. Ntshona and Turner (2002) note that while cattle and goats are consumed at both rituals connected with ancestor worship and other ceremonies, sheep are often only consumed at ceremonies. In the case of a man's funeral an ox may be slaughtered, while for a woman's funeral a cow is slaughtered. The size of the livestock may depend on household wealth and the number of people who need to be fed (Ainslie, 2002b). Typically two beasts are slaughtered, one on the day of the funeral and another approximately a year later (Kepe, 2002). In Peddie district, Ainslie (2002b) noted that people often preferred to slaughter cattle for ritual purposes. Outside of these events people consumed sheep as part of their red meat and protein intake and would only consume cattle if they died of old age or illness (ibid.; see also Ntshona and Turner, 2002). Kepe (2002) noted similar practices in the Lusikisiki district.

The provision of various red meat types and other food stuffs at social ceremonies and ritual events is important in respect to supplementing food intake and to food security in rural areas, not least because such events might be the only time that some poor rural people are able to diversify their food intake and obtain significant portions of animal protein. However, the contribution of these events to food security and nutrition is an under-explored area and further research is required. Such research needs to identify the frequency of attendance of such events and the diversity of food consumed by attending adults and children. At a time when deaths are on the increase as an unfortunate consequence of HIV and AIDS afflictions it is important to determine how this pandemic impacts on the accessibility to ritual and ceremonial foodstuffs and the attendance of such events.

4.3.4.3 Gender and age

Men and children often receive the largest portions of food, and women, despite being responsible for food procurement and preparation, received smaller portions (Kruger et al., 2008). Mothers often ate smaller portions of food to ensure that their children got more food and to save food for future use (Kruger et al., 2008). It was noted that children and men did not always enjoy eating vegetables (Love et al., 2001). Hart and Vorster (2007) report that rural men and the youth do not generally like African Leafy vegetables, although the youth acknowledged that socioeconomic circumstances resulted in them consuming these out of necessity, rather than preference, while some men preferred only certain ALVs. Kota (2006) reports that Xhosa men do not typically consume African leafy vegetable relish (*imifino*).

Tshihwanambi (2007) found that children were often not allowed to eat certain foods (considered taboo for children) but were forced to eat others. She also notes that some foods were in fact considered children's foods (e.g. snacks including biscuits, sweets and potato/maize crisps) and were by in large not consumed by adults (ibid. 68-72). Most commonly avoided foods for children between 10 and 13 years of age included: chicken pelvis and drumstick, chicken gizzards, beef, beef and chicken liver, sausage, fresh fish, eggs, sour milk, traditional beer, alcoholic drinks, tea and chilli sauce. On the other hand children were forced to eat certain foods including: Jute or Jew's Mallow leaves, pumpkin leaves, Amaranthus leaves, Chinese cabbage, spinach, cabbage, soft maize porridge and dried vegetables. The decision to provide these foodstuffs is based on cultural rules and perceptions of health as understood by parents, especially mothers and grandmothers who made the household food consumption decisions (ibid. 72, 107). Tshihwanambi also notes that sometimes elder children may make decisions about younger children's eating habits, especially when female adults are busy or not at home, and cites other studies where such practices were found (2007: 107-108).

Hunter et al. (2007: 171) found that households with older age members were more likely to grow traditional crops than were households with younger age members. They suggest that this pattern may be indicative of attrition in the use of traditional crops by the youth, which could be a cause for concern, as these plants provide many necessary nutrients. Amongst elderly households there is still a preference for traditional foodstuffs when these are available (Viljoen et al., 2005; Hart and Vorster, 2007). Hart and Vorster (2007) note that elderly women often cultivated and prepared traditional foods when they could, as they said this enabled them to remain in touch with their traditional ways. However, both the studies by Viljoen et al. (2005) and Hart and Vorster (2007) note that other ingredients are often added during the preparation of ALVs and other traditional foods in order to suit the modern palate.

The studies by Hart and Vorster (2007) and Vorster et al. (2008) report that the type of crop and the purpose for which it is produced are often determined by cultural gender roles and responsibilities. Men were often responsible for cash crops while women had the overall responsibility for household food crops, even if they sold small amounts of these crops. Cash crops tended to be 'exotic' commodity crops while food crops tended to be 'traditional' crops. This type of power relationship, in which women are responsible for certain crops and men for others, is also manifested in rural households in other ways. For example, studies among farm workers and rural communities in the North West indicate that power relationships often determine intra-household food access, in that household availability and access to food is determined by the person exerting control over crucial household resources (Lemke et al., 2003; Lemke et al., 2009). In particular contexts, where power relationships are more equitable, as in some female-headed or households a better level of food and nutrition security is obtained (Lemke et al., 2003).

4.3.4.4 Acculturation

Black South Africans have undergone a gradual shift towards a western-oriented diet during the past four decades (Viljoen et al., 2005). High energy dense foods are a feature of the 'Western' lifestyle, e.g. fast food or take-away meals and snacks typically contain high levels of fat and sugar. Temple and Steyn (2009) report on a study by Prentice and Jebb which stated that the average British diet was almost two-thirds more energy dense than that of the average traditional African diet (Gambia was used as an example). This leads Temple and Steyn to conclude that the average South African diet, falling almost midway between that of Britain and Gambia, represents a transitional state between the traditional African diet and the western diet. Steyn et al. (2001) have described this state in South Africa as 'nutrition in transition' (cited in Temple et al. 2011). Viljoen et al. (2005) note that many European dishes and preparation practices have been included into the diet of the residents of Mmotla in the North West Province (e.g. salads with lots of mayonnaise). Food preparation and consumption habits used by other races and classes are often learned when in contact with these groups and are subsequently disseminated within households (Viljoen et al., 2005).

4.3.4.5 Social networks

Important activities that enable people to access food within their immediate environment are social networks and relationships between family, friends and neighbours. However, few of the studies make mention of the significance of social networks. Spiegel (1995) has suggested that extensive family and community networks still prevail for the sharing of resources (including resources for agricultural production) and food. McAllister's (2001) study on agriculture, labour and reciprocity in the former Transkei and the comprehensive study of cattle production in the Eastern Cape (see Ainslie 2002a and 2002b, Kepe 2002, and Ntshona and Turner 2002) indicate the importance of social networks in accessing food, either as part of local working parties, neighbourhood groups or through the attendance of ceremonial and ritual events. In KwaZulu-Natal, Kaschula (2008: 179) found that social networks might be important to "food access and the use of environmental resources or natural capital as food security coping strategies". She also reports that food donations from family and neighbours far outweighed any other coping strategy in terms of cultural acceptability, regularity and reliability.

HIV/AIDS afflicted individuals and households are often heavily reliant on social networks for food donations, care for the sick and child-minding. The stigma attached to HIV/AIDS might compel affected households to reduce their pre-mortality or pre-illness practices of harvesting in the wild because of their tenuous positions of dependency in socio-cultural hierarchies (Kaschula, 2008).

4.3.4.6 Convenience and time

The Love et al. (2001) and Viljoen et al. (2005) studies note that preparation time is an important factor as lifestyles have changed and people do not want to spend a lot of time preparing food. Both studies noted that frying was considered a quicker form of food preparation than boiling, baking or grilling and both meat and vegetables were fried when food needed to be prepared quickly. Viljoen et al. (2005) also note that vegetables were sometimes eaten raw in order to reduce preparation time. Viljoen et al. (2005) noted that bread was included into the diet, as it was readily available and was very convenient and quick to prepare. It was often eaten twice a day as a replacement to maize porridge and was served with readily available condiments or spreads (vegetables as well as jams and peanut butter). The same study noted that maize was often only prepared when there were a significant number of household members present. When this was the case, sufficient porridge would be prepared and eaten again at the next meal.

The preparation of some cultural dishes is time consuming and while they are high in nutrients, the time factor means that they are often only consumed on special occasions in the traditional social calendar (Tshihwanambi, 2007; Viljoen et al., 2005). Often western or modern foods are also consumed on these occasions, as they can be quicker to prepare, but also so that the host can cater for a variety of palates and preferences (Viljoen et al., 2005). The amount of time required to prepare and cook legumes is considered a constraint by some and those who can afford to replace dry beans with processed soya products often do so (Love et al., 2001; Kruger et al., 2008).

Traditional beverages are usually replaced with cordials, sodas and 'modern' beverages such as tea and coffee because of their convenience. However the study by Viljoen et al. (2005) notes that during traditional celebrations traditional beverages were brewed and the making of traditional beer was still considered the sign of a good Ndebele woman. Hart and Vorster (2007) noted a similar trend amongst the Tsonga in Limpopo with regard to the brewing of marula beer.

4.3.4.7 Knowledge and education

Advertisements and advertising were not directly mentioned in any of the studies, although Love et al. (2001) and Viljoen et al. (2005) mention that mass media such as television, radio and magazines may influence food choices. In their study in KwaZulu-Natal and the Western Cape, Love et al. (2001) note the routine purchasing habits may determine food intake, as people tend to stick with what they know and thus limit the inclusion of new foods into their food basket. Similarly, Temple and Steyn (2009) point out that many South Africans are unlikely to have the level of dietary knowledge required in order to select foods that have low energy density, and that they also need to be motivated to select low energy dense foods. The high sugar and fat content of many high energy dense foods makes them tastier and therefore preferential to their low energy dense counterparts. Love et al. (2001) report a respondent who claimed that the addition of fat improved the taste of food, by making food taste meaty.

Hunter et al. (2007), Hart and Vorster (2007) and Vorster et al. (2008) all report that female respondents considered ALVs to be more nutritious in comparison to the exotic vegetables they consumed and cited this as one of the reasons for consumption. These statements are generally backed up by scientific studies (Afolayan and Jimoh 2008). Hart and Vorster (2007) and Hart (2011) found that traditional knowledge relating to certain crops as well as knowledge about what could be grown in the local environment determined the crops produced for household food. Traditional knowledge relating to production, harvesting in the wild and preparation of particular traditional foods was cited as a reason for consuming these foods (Hunter et al., 2007, Hart and Vorster 2007). Kaschula (2008) notes that local botanical knowledge is important when food is harvested from the wild. In contrast to her quantitative data, Kaschula's qualitative interviews indicate the likelihood that households afflicted by AIDS might reduce their use of wild foods due to labour shortages, lack of knowledge about less common edible plants, and also the stigma attached to the disease. Death of a household member can affect livelihood activities and thus food choices through the loss of skills and knowledge essential to these activities, as adult mortality might occur before such expertise is transferred (Kaschula, 2008).

In her Eastern Cape study, Kota (2006: 21), notes that despite changes brought about by modernisation, some households still use traditional methods for storing and preparing food, and that they also consume traditional foodstuffs. However, she acknowledges that in both rural and urban households people are often ignorant of the value of traditional food and consequently avoid these foods, considering them to be the food of the poor. Similar statements are reported in the studies by Modi et al. (2006), Hart and Vorster (2007), Vorster et al. (2008), and Afolayan and Jimoh (2009). Kaschula's (2008) study in KwaZulu-Natal highlighted the notion that western and exotic foods were associated with notions of eating well. Informants would thus eat nutritionally inferior western foods in place of more nutritious indigenous/traditional food, assuming that these western foods were more nutritious than traditional foods.

4.3.5 Individual environment

This section looks at new or adopted ideas and ideals that are influencing food choices of individuals within households. It largely focuses on ideas and ideals.

4.3.5.1 Ideas

Love et al. (2001) cite reports of persistent food preparation behaviour as reasons for why foodstuffs are often prepared in the same way without any change. The example they use is the regular inclusion of fat in preparation methods. Fat is considered to be an essential ingredient.

Viljoen et al. (2005) report that certain foods are associated with joyous and special occasions. They note that on weekends special foods were prepared and served because the entire family/household was usually together. Weekends were also a time when celebrations were held due to the greater presence of household members, family and friends, but also due to availability of income (Viljoen et al., 2005).

Changes in diet are also a result of perceived or informed understandings of the effects of certain foods one's health. Viljoen et al. (2005) report that people included brown bread in their diet and reduced consumption of sugar, maize porridge and oil following the advice from the clinic sisters. The study also noted that perceptions about what was considered good or bad for one's health also played a role. While some people ate traditional sorghum porridge (locally an expensive item) for health reasons others avoided certain traditional foods as they found that it had started to disagree with them as they got older.

Kaschula (2008: 178) reports that misunderstandings about what constitutes 'good food' and 'eating well' is aggravated by local ideas that generally associate good health and optimal nutrition with cultivating or purchasing western or exotic foods. Such ideas result in people ignoring healthier wild foods in favour of less nutritious western foods. She points out that such ideas about eating well resulted in AIDS-afflicted people ironically avoiding wild foods in the interests of good health, following local government AIDS awareness campaigns that emphasised the importance of 'eating well'.

4.3.5.2 Ideals and aspirations

The study by Viljoen et al. (2005) highlights the influence of social aspirations in that the youth felt that consuming western food was an indication of social status and good education. Particularly, the youth consider consumption of traditional foods to be associated with poverty and backwardness (Hart and Vorster, 2007; Vorster et al., 2008; Afolayan and Jimoh, 2009) and western foods are associated with higher social status and of being 'educated' (Viljoen et al., 2005). However, despite the disdain for ALVs, Hart and Vorster (2007) note that the youth reported planting, harvesting and eating traditional food crops as a consequence of their inability to afford to purchase 'modern' or preferred food as regularly as they would have liked.

4.4 DISCUSSION, IDENTIFICATION OF KNOWLEDGE GAPS AND CONCLUSION

Information on the reasons for the foods consumed by rural South Africans is sparse and fragmented, with only one study really focusing on some reasons for contemporary food choices. Some data were found in studies with other research aims. However, the data gleaned, and drawing heavily on the work of Viljoen et al. (2005), does allow us to provide a tentative framework that could be used to aid further investigation in this topic. In this framework the themes and factors influencing contemporary food intake, highlighted by Viljoen et al. (2005), should also include the effects of HIV/AIDS and other diseases (including death) on food choices. This has been included in the framework below (Figure 1) in the Economic and Political Environment. Death and disease will first and foremost result in an economic shock for the household and thus negatively affect the economic environment of the household before changes in other environments are felt. Economic factors (available financial resources and assets, labour ability and household size) will be immediately affected.

Physical Environment Natural resources Seasonal variation Physical environment and infrastructure	*Availability and Accessibility*
Economic and Political Environment Employment Opportunities Government and other Support Services Local Tenure Arrangements Disease and Death	*Affordability*
Socio-cultural Environment Urbanisation and Migration Tradition, Culture and Religion Gender and age Acculturation Social Networks Convenience and Time Knowledge and Education	*Acceptability*
Individual Environment Ideas Ideals and Aspirations	*Individual Choice*

Figure 4.1: Framework of the themes and factors influencing food intake

Following from the findings of this study, which does not claim to be comprehensive, some further points require deeper investigation or inclusion into future studies:

- There is a paucity of studies focusing on the reasons for contemporary food intake by rural households across South Africa. Given that almost all of the reviewed studies are micro-level studies we only have very limited information on food choices for households within specific villages.

- The studies reviewed are often unclear as to how poor people are defined in a particular study making it impossible to consider the different levels of poverty and associated food consumption patterns at different levels. Nor do there appear to be any studies which specifically focus on food intake variations at different poverty levels.
- Moreover, and despite a hierarchy of themes we have little information about the priority or hierarchy of food choices. For example, income might be the most important reason for food choices – even for the rural poor. Furthermore, there is little information about the interaction between factors, such as how employment and unemployment and food price hikes and fluctuations impact on food choices.
- Most studies simply consider race as two distinct groups: black and white. Consequently the authors discuss different cultural groups as one. This overlooks the variation between different races and also cultural distinctions within these groupings. More care should be taken in future to focus on cultural groups and different ethnic and racial categories and the interaction of cultural factors that influence food choices and which may be determined by other factors such as spatial location and population density.
- A more nuanced distinction of black South African's is required. Such a distinction needs to acknowledge the wealthier black South Africans in both rural and urban areas rather than assume that the primary distinction is spatial location.
- How seasonality determines food choices is extremely under-researched. Seasonality not only influences crop production, the availability of foodstuffs in the wild, but it also influences employment and thus purchasing power, as well as the dependency upon and strength of social networks.
- The impact of HIV/AIDS on individual and household food choices is not really researched, except by means of a strong focus on its impact for harvesting in the wild. A focus which largely looks at the relationship between HIV/AIDS, food security needs, economic status and the environment. The identified literature does not cover the fact that many sick people and those living with HIV/AIDS have specific food preferences and eating abilities which are determined by feelings of nausea, mouth and stomach ulcers and the inability in some cases to digest solid food. HIV/AIDS and the context thereof, undoubtedly affects food consumption choices, access, preferences and needs but the actual relationships are far from clear. The lack of clarity is perhaps a result of the limited literature reviewed on HIV/AIDS. A more comprehensive review of the HIV/AIDS literature might shed more light on the impact of HIV/AIDS on food choices and behaviour and is recommended in future studies.
- Little attention appears to be paid to the contribution that social networks, including working party and neighbourhood group membership, and ritual events make to food security in rural areas. Most studies generally focus on the contributions of purchasing, producing or gathering food from the wild. For the poor, participation in such groups and attendance of events may be their primary sources of animal protein. In particular, in an era of HIV/AIDS the frequency and attendance of events such as funerals is worth considering in terms of the possible contribution to food security.
- How individuals make decisions regarding food choices and how they act independently of household decisions in this regard is not aptly considered in the studies reviewed, i.e. individual responses to intra-household allocation of food is ignored.
- Many of the directly relevant studies appear to be constrained by their limited involvement of colleagues from other disciplines, particularly the social sciences. For example, many studies rely on structured interviews and/or questionnaire surveys for determining the yields of particular crops and the off-take of livestock. However, these figures are often under-reported for a variety of culturally specific reasons and the recorded figures are often incorrectly determined and misleading. Furthermore, there is often a reliance on recall without any

concurrent observation to validate the information provided. Current social science studies and ethnographies in South Africa directly focusing on food choices and preferences also appear to be scarce and scholars of most disciplines do not appear to be devoting significant attention to the subject in this country.

Nevertheless the following may be concluded:

The macro and meso level factors tend to influence the decisions made at micro-level such as availability, accessibility, affordability, acceptability and household and individual decision making. The reasons for food intake are determined by a range of factors. These include individual, household, cultural and ethnic group preferences, location, season, income and affordability, historical factors, knowledge and education, and social networks, as well as the impact of HIV/AIDS on individuals and households. Therefore micro-level case studies are the best means of understanding the diversity of reasons for food intake. However, most of the existing micro-level studies only mention one or two aspects that are relevant to understanding the reasons for contemporary food intake, as their primary focus is different. More in-depth micro level case studies are required in order to obtain better information on the topic and especially studies that consider the local context, cultural variation, social networks and attempt to prioritise food choices at different times or during different life experiences. Having said that, it is also important to understand how macro level factors (high prices, food distribution, agricultural support services, climate change, etc.) impact on the micro level context and influence local reasons for food intake. It is also important to understand reasons for food intake in different localities at a national level and this could be done by means of including appropriate questions (based on solid fieldwork) into national surveys.

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CHAPTER 5

FOOD SELECTION GUIDANCE

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5.1 INTRODUCTION

The assessment of food intake is only complete when the intake data are properly interpreted. For planning food and nutrition programmes, the assessment phase should be followed by scientifically sound and context-specific recommendations that address potential nutritional gaps which emerged from the assessment.

Against the backdrop of the situation assessment presented in Chapter 3 and some core definitions (section 5.2), this chapter has the following foci. We start off with a brief introductory overview of dietary standards for evaluating dietary intake (section 5.3). This is followed by a characterisation of the nutritional gaps in the food intake of rural, poor South Africans. In section 5.5 are recommendations for foods and / or crop / animal products (in the form of food selection guidance) for follow-up research, taking knowledge of *where* people obtain their food from (Chapter 3) and *why* people eat the food they do (Chapter 4) into account. The energy, macro- and micronutrient contents of these foods are presented following a brief overview of food composition data within the process of dietary assessment, with special emphasis on the South African situation. The Chapter ends with a more in-depth discussion of the nutrient composition of two crops: orange sweetpotato and dark green leafy vegetables as a sub-group.

5.2 TERMINOLOGY / OPERATIONAL DEFINITIONS

In order to avoid misunderstanding across disciplines some core terminology, specifically relevant to this Chapter and Chapter 6 (which directly builds on Chapter 5) is explained. (Most of these terms are also included in Chapter 2).

5.2.1 Evaluation of food intake (Dietary evaluation)

Evaluation is understood to be the interpretation / judging of the diet quality of the food intake data using appropriate dietary standards as yardstick.

5.2.2 Diet quality

Diet quality in this text refers to the *nutritional (dietary) adequacy* (as opposed to aspects such as organoleptic properties, microbiological safety, etc. of food, or nutritional intake from non-conventional foods or supplements) based on total food intake of individuals or groups (ideally over time).

5.2.3 Dietary standards

Dietary standards are tools used to evaluate dietary intake; this includes nutrient-based standards, diet quality scores and food based dietary guidelines; mostly these standards are quantitative (to find confidence of adequacy), but some are qualitative (to find probability of adequacy).

5.2.4 Nutrient-based standards

This refers to nutrient (as opposed to food, food component or dietary) intake values or references.

5.2.5 Diet(ary) quality scores

Diet indices or composite dietary tools (often numerical) that measure (aspects of or total) food intake; usually predefined; mostly, but not always food- or dietary pattern-based.

5.2.6 Nutritional gaps

This refers to the difference between a current intake (in terms of nutrients or foods) and a desirable dietary standard or other measure of diet quality.

5.2.7 Nutrition security

Nutrition security is determined by the availability of health services, a healthy environment (to ensure effective biological utilization of foods consumed), the quality of care an individual receives, in addition to household food security.

5.2.8 Food composition database

Food composition refers to the chemical “make-up” of foods. A food composition database can be defined as a paper-based or electronic tabulation which represents an approximation of the real nutrient (and non-nutrient) content of food (based on Joyanes & Lema, 2006). Sometimes *reference* databases (compiled and distributed by governments or other authoritative bodies) and *user* databases (compiled by software companies or individuals for use in specific settings) are distinguished (Stumbo, 2008). For the purpose of this report the “Condensed Food Composition Tables for South Africa” of 2010 compiled by the Nutritional Intervention Research Unit of the Medical Research Council (MRC) of South Africa based on information from the South African Food Data System (SAFOODS) (Wolmarans et al., 2010), is considered the reference database.

5.2.9 Food components

Chemically foods contain nutrients and non-nutrient components. Nutrients are substances that humans need to ingest (usually through food) for maintaining good health. The criteria for essentiality is that absence of the nutrient from the diet results in characteristic signs of a deficiency and these signs are prevented only by the nutrient itself or a specific precursor of it (Shils et al., 2006).

The *macronutrients* in human nutrition are broadly classified as proteins, fats and carbohydrates. They provide energy, meaning the caloric (or kJoule) input resulting from the intake of foods. Even though alcohol also provides energy, it is not considered in this report. *Micronutrients* are consumed in small amounts and include minerals (inorganic elements) and vitamins (organic substances). Non-nutrients can include a wide range of naturally occurring or added substances, ranging from toxins, to colourants and flavourants. From a nutrition perspective, non-nutrients also refer to components of food which may have structural functions in the cells of the foods, e.g. cellulose, or could have health-promoting properties, e.g. phytochemicals. In some cases the boundary between nutrients and non-nutrients is vague, e.g. for dietary fibre or water. In this project the focus is on the “classical” nutrients listed in table 5.1 below (based on Shils et al., 2006).

Table 5.1: Nutrients included in food composition report

Nutrient	Description	Comments / alternative nomenclature or forms / abbreviation
Proteins	Nitrogen-containing nutrient consisting of essential, conditionally essential and non-essential amino acids. High quality proteins provide the essential amino acids in sufficient quantities. Usually the proteins from animal sources are of high quality.	1 g protein yields 4 kcal (17kJ) of energy
Fats	Fats and lipids are defined as a class of compounds soluble in organic solvents. Triglycerides (triacylglycerols) make up the largest proportion of dietary lipids. Some fatty acids are essential.	1 g fat yields 9 kcal (37kJ) of energy
Carbohydrates	Apart from substances with the simple formula $C_{12}(H_2O)n$ this includes more complex compounds (oligo- and polysaccharides), sugar alcohols and derivatives.	1 g carbohydrate yields 4 kcal (17kJ) of energy
Calcium	Mineral / Inorganic element	Ca
Iron	Mineral / Inorganic element	Fe
Zinc	Mineral / Inorganic element	Zn
Copper	Mineral / Inorganic element	Cu
Manganese	Mineral / Inorganic element	Mn
β-carotene	A pro-vitamin A carotenoid produced by plants	See text
Vitamin A	Nutritional term for a family of essential fat-soluble dietary compounds that are structurally related to the lipid alcohol retinol. It includes the pro-vitamin A carotenoids	Retinol
Thiamin	Water-soluble vitamin	Vitamin B_1
Riboflavin	Water-soluble vitamin	Vitamin B_2
Niacin	Water-soluble vitamin	Nicotinic acid or nicotinamide
Vitamin B_6	Water-soluble vitamin	Pyridoxin, pyridoxal or pyridoxamine
Folate	Water-soluble vitamin	Pteroyl triglutamate
Vitamin B_{12}	Water-soluble vitamin	Cobalamin
Vitamin C	Water-soluble vitamin	Ascorbic acid

5.2.10 Nutrient density

Nutrient density refers to the amounts of key nutrients contained per 100 kcal of a food (Drewnowski, 2009). Nutrient dense foods and beverages provide vitamins, minerals and other substances that may have positive health effects, with relatively few kilojoules (energy). Examples include vegetables, fruit, whole grains, low-fat dairy, lean meats and poultry (when prepared without solid fats or added sugars).

5.2.11 Plant foods: Groups and sub-groups

Since Thompson et al. (2011) found considerable disagreement and inherent vagueness related to the terms fruit, vegetable and other food domains amongst different groups of the American public, it was deemed necessary to clarify the meanings attached to these constructs in this report. Table 5.2 summarizes the nomenclature and table 5.3 the grouping of fruit and vegetables based primarily on the work of Pennington et al. (2009; 2010). The grouping is based on similarity in food composition (see "nutritional properties") and on easily identifiable classification properties, and also taking into account botanical family, part of plant, colour and antioxidant capacity (Pennington & Fisher, 2010).

Table 5.2: Nomenclature of plant foods

Plant food	Description
Fruit	Although the botanic term "fruit" refers to the seeds and surrounding tissues of a plant, the foods that are commonly referred to as " fruit" for culinary purposes and in human nutrition, are pulpy seeded tissues that have a sweet (e.g. oranges, apples, pears) or tart (e.g. lemons, cranberries) taste. They are often eaten as snack, dessert or sweet side dish to a meal (Pennington & Fisher, 2009).
Vegetables	In the culinary context this refers to edible plant parts including • Stems and stalks (e.g. celery) • Roots (e.g. carrots) • Tubers (e.g. potatoes) • Bulbs (e.g. onions) • Leaves (e.g. spinach) • Flowers (e.g. artichokes) • Some fruit (e.g. cucumbers, pumpkin, tomatoes) • Seeds (e.g. beans, peas). They are less sweet than fruit and are usually consumed as salads, cooked side dishes and savoury appetizers. Seen in this way avocado is included and also mushrooms (fungi) and sweet corn (which is usually classified as cereal grain (Pennington & Fisher, 2009). Herbs and vegetables used as spices are not included.
Legumes	This refers to peas, beans and peanuts (even though typically used as nut) (Pennington & Fisher, 2009).

Table 5.3: Fruit and vegetable subgroups

	Nutritional properties* At least per 100 g:	**Foods**** (alphabetically)
Dark green leafy vegetable subgroup (for Project K5/1954//4 the foods in this group were sub-divided into those that grow in the wild and those that are home-grown)	50% DRI for vitamin C and K 25% DRI for folate 10% DRI for K, Ca, Mg, Fe, Cu, Mn, vitamin B_6. Sub group highest in β-carotene, and lutein+zeaxanthin	**African leafy vegetables***, i.e. amaranth, vigna (cowpea), corchorus (jute), cleome (spiderplant), citrillus (bitter watermelon), cucurbita (pumpkin), solanum (black nightshade), bidens (black jack), pumpkin, sweetpotato, beet greens,** collards, **kale,** mustard greens, parsley, romaine, **spinach, Swiss chard,** turnip greens
Cabbage family vegetables subgroup	50% of DRI for vitamins C and K 10% DRI for Mn, vitamins B_6 and folate	Broccoli, broccoli raab, Brussels sprouts, **cabbage** (**green** and red), cauliflower, Chinese broccoli, **Chinese cabbage (Brassica rapa)**

	Nutritional properties* At least per 100 g:	**Foods**** (alphabetically)
Lettuces subgroup	50% DRI for vitamin K 10% DRI for Mn, vitamins C and folate	Butterhead lettuce, endive, iceberg lettuce, leaf lettuce (green and red), watercress
Legumes subgroup	25% DRI Cu, folate 10% DRI for dietary fibre, Mg, Fe, Zn, Mn, vitamin B_6	Black-eye peas (mature), green peas, lentils, lima beans (immature), kidney beans (mature), mung beans (mature), navy beans (mature), pigeon peas (mature), pinto beans (mature), soybeans (mature) **cowpeas (vigna, mature), bambara and other groundnuts (peanuts)**
Deep orange/yellow fruit, roots and tubers subgroup	10% DRI vitamin C Subgroup highest in α-carotene and second-highest in β-carotene	Fruit: **Apricot, cantaloupe (orange-fleshed), mango**, nectarine, **peach (yellow), papaya** Vegetables: **Butternut squash, carrot,** hubbard squash, **pumpkin**, **sweetpotato (orange-fleshed)**
Citrus family fruit subgroup	25% DRI for vitamin C	Clementine, grapefruit (white and pink), kumquat, lemon, lime, orange, tangerine
Tomatoes and other red vegetables and fruit subgroup	50% DRI vitamin C Subgroup highest in lycopene	Fruit: Cherries, **guava,** pomegranate, watermelon Vegetables: Beet, red pepper, rhubarb, tomato
Red/purple/blue berries subgroup	10% DRI for dietary fibre, Mn, vitamin C	Blackberries, blueberries, boysenberries, cranberries, raspberries, strawberries
Allium family bulbs subgroup	50% DRI for vitamin K 25% DRI for Mn,, vitamin B_6 10% DRI for Cu, vitamin C	Garlic, leek, onion, scallion
Other subgroup	10% DRI for vitamin C	Fruit: Apple, artichoke, Asian pear, banana, casaba, melon, date, fig, grapes, honeydew melon, kiwi, pear, pineapple, **plum**, raisins, **loquat** Vegetables: Asparagus, avocado, celery, corn, crookneck squash, cucumber, eggplant, **green pepper**, Jerusalem artichoke, jicama, mushrooms, okra, parsnip, potato, radish, rutabaga, snap beans, snowpeas, turnip, zucchini

*DRI refers to Dietary Reference Intakes; Pennington and Fisher (2010) used highest allowance for a non-pregnant, non-lactating adult over 18 years. This was adopted in this study.

** Foods in black are directly from Pennington and Fisher (2010), but not recommended for further investigation in this project. Green and red are those plant foods chosen for further investigation in Project K5/1954//4. Foods in **red:** chosen from Pennington and Fisher (2010) groupings for possible further investigation in Project K5/1954//4. Foods in **green**: added to or modified from Pennington and Fisher (2010) groupings for contextualisation to rural South African situation and potentially meeting shortfall micronutrients and criteria of Project K5/1954//4.

*** African leafy vegetables is a term adopted by Jansen van Rensburg at al. (2007) to refer to the collective of plant species which are used in human nutrition as leafy vegetables and which are called *morogo* or *imifino* by African people in South Africa.

5.2.12 Food selection guidance

Terms such as dietary or nutrition recommendations, goals, guidelines, guides, checklists, (food or healthy eating) baskets, etc. may all denote some target or desirable food intake or availability / access to food, often with confusing and indistinct meanings. In this project food selection guidance is the term used to describe the project-specific recommendations which attempt to encapsulate the criteria developed in this project for follow-up research.

5.3 OVERVIEW OF DIETARY STANDARDS

The assessment of dietary adequacy is much more complex than meets the eye. In an attempt to increase clarity in this field and to work towards harmonization, much international debate has recently focussed on this topic of defining dietary requirements and needs. Not only are there still many knowledge gaps in terms of what constitutes a nutritionally adequate diet and how to measure and express this, but there remains much confusion in terms of terminology within the scientific community and across countries (King & Garza, 2007; Uauy, 2009).

The intention of this section is to present a very simplistic overview of dietary standards, without entering the ongoing academic debates. Where possible, reference is made to the South African situation.

5.3.1 Nutrient-based dietary standards

Nutrient intake values have been published by many countries, regions and societies, for example the United States of America (USA) / Canada, United Kingdom (UK), European Communities, and the World Health Organization (WHO) / Food and Agricultural Organization (FAO), often using differing terminology. The current state of matters was summarised by King et al. (2007) who also pleaded for and suggested “harmonised” terminology in order to reduce confusion (Table 5.4).

In South African surveys the USA / Canada Dietary Reference Intakes (DRI) are used most of the time when evaluating dietary intake. Occasionally the WHO/FAO values are applied, and sometimes the Dietary Reference Values (DRV) from the UK are also mentioned. A review of dietary assessment studies in the European Community revealed that also in these countries there was no uniform approach to assessing nutrient intake adequacy, even though the most quoted text was the Institute of Medicine (IOM) – the basis of the RDA, often also called the INL_{98} (Roman-Vinas et al., 2009a; Tabacchi et al., 2009).

It is important to distinguish the dietary standards (Table 5.4) from the nutrient reference values used for labelling and marketing of food products, where the nutrient composition of a product (usually per 100g or per serving) is compared with recommended intakes (Vorster et al., 2007). South African labelling is regulated in the Foodstuffs, Cosmetics and Disinfectants Act of 1954 which is guided by the standards set out by the Codex Alimentarius Commission.

All nutrient intake values are intended for healthy people. Nutritional requirements of healthy people are, in turn, affected by aspects such as life-stage (Atkinson & Koletzko, 2009), diet- and host-related factors which influence bioavailability (Gibson, 2009), and genetic variation (Stover, 2009). It is finally important that due consideration be given to the specific nutrient intake value (e.g. AI) within a system (e.g. the USA / Canada / IOM) and the cut-off (e.g. 67% below AI) that is chosen when evaluating diets.

Table 5.4: Terminology of selected nutrient intake values

Description	USA/Canada	WHO/FAO	UK	Suggested "Harmonized term"
Umbrella term for the set of recommendations	Dietary reference intake (DRI)	-	Dietary reference value (DRV)	Nutrient intake value (NIV)
Average requirement	Estimated average requirement (EAR)	-	Estimated average requirement (EAR)	Average nutrient requirement (ANR)
Recommended intake level	Recommended dietary allowance (RDA)	Reference nutrient intake (RNI)	Reference nutrient intake (RNI)	Individual nutrient level, x=percentile chosen (INL_x)
Lower reference intake	-	-	Lower reference nutrient intake	-
Safe intake	Adequate intake (AI)	-	Lower end of safe intake range	-
Upper level of safe intake	Upper tolerable nutrient intake level (UL)	Upper tolerable nutrient intake level (UL)	Upper end of safe intake range	Upper nutrient level (UNL)
Appropriate macronutrient distribution range	Acceptable macronutrient distribution range (AMDR)	Population mean intake goals	Adequate macronutrient distribution range (AMDR)	-

Source: Adapted from King et al., 2007

5.3.2 Diet(ary) quality scores

Since people eat food and not nutrients, and in a quest to evaluate whole diets, food combinations, variety or patterns (not only specific nutrients), recent years have seen the development of many diet quality scores or indices. Critical reviews of these have been published (Kourlaba & Panagiotakos, 2009; Roman-Vinas et al., 2009b; Waijers et al., 2009). In Table 5.5 a selection of diet quality scores are listed. In the South African setting some of these have already been used, e.g. the diet diversity score (DDS) and the mean adequacy ratio (MAR).

Application of different dietary standards to the same food intake data does not necessarily lead to the same results, nor can diet quality necessarily be predicted from social class information (Darmon & Drewnowski, 2008). This must be kept in mind when the findings of studies applying different dietary standards are compared or merged. As mentioned already in the critical analysis of deliverable 1, the South African food intake studies not only employed different data collection techniques for the dietary assessments, but also used different dietary standards in the evaluations.

Table 5.5: Examples of diet quality scores

Name	Abbreviation
Diet Diversity Score[a]	DDS
Diet Quality Index[b] (plus revisions and adaptations [c])	DQI
Dietary Guidelines Index[a]	DGI
Food Pyramid Index[a]	FPI
Food Variety Score[a]	FVS
Food-based Quality Index[a]	FBQI
Healthy Diet Indicator[a]	HDI
Healthy Eating Index (plus alternatives) [a]	HEI
Healthy Food Index [a]	HFI
Mediterranean Diet Score (plus adaptations)[d]	MDS
Nutrient Adequacy Ratio & Mean Adequacy Ratio [c]	NAR/MAR

[a] based on foods or food groups
[b] based on food groups and nutrients
[c] based on nutrients
[d] based on food groups, supplemented with a ratio reflecting the fatty acid composition of the diet and alcohol (the adapted MDS consists solely of food groups)
Sources: Kourlaba & Panagiotakos, 2009; Roman-Vinas et al., 2009b; Waijers et al., 2009

5.4 NUTRITIONAL GAPS IN THE FOOD INTAKE OF RURAL POOR SOUTH AFRICANS

5.4.1 Energy

The National Food Consumption Survey (NFCS) of 1999 (Labadarios et al., 2000) as well as several smaller studies indicated inadequate energy intakes among children (e.g. Oldewage-Theron & Egal, 2010). The NFCS further showed an association between energy intake and stunting at the national level (Labadarios et al., 2000). Yet, adult obesity in rural areas is high (SADHS, 2003:277) and childhood obesity is on the increase (Kimani-Murage et al., 2010).

5.4.2 Macronutrients

Despite the fact that low energy intakes were reported, protein intakes were shown to be adequate (Faber & Benadé, 2001; Labadarios et al., 2000; Oldewage-Theron & Egal, 2010). The type of protein (animal origin versus plant origin) may however be of concern, as consumption of animal products is generally low. Approximately 60% of the dietary protein is of plant origin (MacIntyre et al., 2002; Oldewage-Theron & Egal, 2010). The nutritional quality of the various plant proteins may differ (Young & Pellet, 1994). Furthermore, the adequacy of total protein intake is also related to energy intake (Millward & Jackson, 2003), complicating general conclusions.

5.4.3 Micronutrients

The NFCS of 1999 showed that a large number of children had an inadequate dietary intake of vitamin A, vitamin C, thiamine, riboflavin, niacin, vitamin B_6, calcium, iron and zinc. Rural children were worse off than urban children (Labadarios et al., 2000). Inadequate dietary intake of various micronutrients was confirmed in smaller studies (Faber et al., 2001; Oldewage-Theron & Egal, 2010).

Micronutrient malnutrition in South Africa is widespread, particularly in terms of vitamin A, iron and zinc. The most recent National Food Consumption survey (NFCS-FB1) showed that 64% of 1-9 year old children had low serum retinol concentrations (an indicator for vitamin A deficiency), 45% had a low zinc status, 28% were anaemic, and 13% had a poor iron status (Labadarios, 2007). Compared to the national survey of 1994 (Labadarios et al., 1995), the vitamin A status of South African children appears to have deteriorated, despite a national vitamin A supplementation programme that was introduced in 2002 and a national food fortification programme that has been in operation since 2003. The poor micronutrient status in rural communities was confirmed in smaller studies (Faber & Benadé, 1999; Faber & Benadé, 2007; Faber et al., 2001; Mamabolo et al., 2006).

Low consumption of foods of animal origin, fruit and vegetables are major contributing factors towards the poor micronutrient status of the rural poor. In addition, maize, which is the most frequently consumed food item by South African children (Labadarios et al., 2000) has a high phytate content, which is an inhibitor of non-haeme iron (Davidson, 1996) and zinc absorption (Turnlund et al., 1984).

5.4.4 Dietary diversity

A variety of food is needed in the diet to ensure an adequate intake of essential nutrients. In general, the South African population consumes a diet of low diversity. At the national level, dietary variety is limited in the majority of the children's diets, with an average food variety score (FVS; number of food items consumed over a 24 hr recall period) of 5.5 and an average dietary diversity score (DDS; number of food groups out of a possible nine) of 3.6. A FVS below 6 and a DDS below 4 were shown to be associated with poor micronutrient adequacy of the diet (Steyn et al., 2006). A study done in Greater Sekhukhune in the Limpopo Province showed that more than 50% of the households consumed fewer than four food groups per day, and that for households with low dietary diversity (below 4), "cereals, roots and tubers" was the only food group that was consumed by at least 50% of the households the day prior to the survey. This study further showed that households with low dietary diversity were also the most impoverished (Faber et al., 2009). In the North-West Province it was shown that urban adults ate a variety of food, whereas rural adults, especially those living on large commercial farms, ate mainly staple foods. The varied diets of the urban adults contributed to higher intakes of most vitamins and iron and to higher serum retinol concentrations. Adults from rural areas had significantly lower dietary intakes of most micronutrients than urban adults. Rural adults had lower intakes of animal protein, fruit and vegetables than urban adults (Kruger et al., 2005).

Low consumption of fruit and vegetables was observed in the NFCS (Labadarios et al., 2000) as well as various smaller studies in the Eastern Cape (Smuts et al., 2008), Free State (Dannhauser et al., 1996; Mpontshane et al., 2008), KwaZulu-Natal (Smuts et al., 2008; Faber & Benadé, 1999; Faber & Kruger, 2005), Limpopo Province (Mamabolo et al., 2006) and Western Cape (Krige & Senekal, 1997; Witten, 2002). Most frequently consumed fruit seem to be apple and banana, and to a lesser extent orange. Most frequently consumed vegetables seem to be leafy vegetables, including cabbage and dark-green leafy vegetables (either wild-growing, home grown or purchased) and tomatoes. Consumption of yellow / orange fruit and vegetables is generally low.

5.4.5 Nutrient density

Nutrient density refers to the amount of (micro) nutrients relative to its energy content (usually 100 kcal). The two most frequently consumed staple foods are porridge made with maize meal and bread (Labadarios et al., 2000). Fortification of both bread flour and maize meal became mandatory in South Africa in 2003. Porridge made with maize meal, which is a bulky food low in nutrient density, is widely used for infant and young child feeding in South Africa (Faber et al., 1997; Faber, 2005; Mamabolo et al., 2004). The impact of the national food fortification programme on infant and young child nutrition will probably be minimal because of the small amount of maize meal that they consume. Infants and young children have high nutritional requirements relative to body size and consume small amounts of food; they therefore require nutrient-dense complementary foods. The complementary diet of infants in rural KwaZulu-Natal was shown to be inadequate for several of the micronutrients, particularly calcium, iron and zinc (Faber, 2005).

5.5 FOOD SELECTION GUIDANCE FOR RURAL POOR SOUTH AFRICANS

When asked: “Is this food healthy or unhealthy?” a standard answer by nutrition professionals would be “Diets, not individual foods, are healthy or unhealthy”. This is the underlying rationale for slogans such as “All foods can fit” by local and international nutrition associations such as the Association for Dietetics in South Africa and the American Dietetic Association.

Food-based dietary guidelines (FBDG) are increasingly used to frame a recommended / healthy diet. They express the principles of nutrition education primarily as foods (as opposed to nutrients) and are intended for use by the general public and are usually phrased positively. Such guidelines typically indicate that some food categories (groups) should be emphasised, whereas others should be limited (WHO, 1996). In South Africa the Department of Health officially promotes a locally developed set of 11 dietary guidelines for people over the age of 7 years. In addition, paediatric FBDG’s have been formulated for healthy children from birth to that age (Bourne, 2007). Currently (i.e. 2012) the South African FBDG’s and the paediatric version are being reviewed, but since the revisions have not yet officially been adopted, the original 11 guidelines are quoted in this report. Equally, the Department of Health is currently (2012) investigating the implementation of a proposed “food guide” (i.e. a visual presentation to support the FBDG). No decisions in regard have been officially communicated.

In spite of the valid emphasis by nutrition professionals on a whole diet as a basis for judging healthfulness, consumers, the food industry and others need guidance on how to identify “better” choices within food categories (groups). This calls for criteria. (Operational) definitions of “nutrient rich” or “nutrient dense” foods are another “hot topic” in the field of nutrition. Numerous indices for characterising “nutritious” foods are currently developed and validated, for example the Nutrient-Rich Food (NRF) index (Drewnowski, 2009), or the Nutrition Score (Nijman et al., 2007), with “nutrient profiling” (understood as the science of categorising foods according to their nutritional composition for reasons [for disease prevention and health promotion]) becoming increasingly popular (Darmon et al., 2009; Maillot et al., 2008; WHO, 2011). Also in South Africa such an initiative is currently underway. The Department of Health has been presented with a nutrient profile model, which has been tested and is accompanied by software for ease of application. An official decision in this regard is also awaited. At the same time it is important to remember that the meanings that consumers attach to “healthy eating” include but are broader than the food composition and health outcomes considered by scientists (Bisogni et al., 2012).

It follows from the above that at this point in time (June 2012) formulating food-based recommendations for addressing nutritional gaps of rural poor South Africans is particularly challenging.

As part of this study a workshop was held (end 2010) to obtain input from different role players in the field of food, nutrition and health for the development of food based recommendations based on pre-determined criteria. Participants were briefed about the project and received a list of possible criteria accompanied by selected papers (Maillot et al., 2010; Nelson et al., 2002; Anderson et al., 2007; Backeberg & Sanewe, 2010; Mc Kinnon et al., 2009).

5.5.1 Guiding principles

Following extensive discussion, workshop participants agreed to recommend the South African FBDG as a whole as starting point in the compilation of criteria (Box 5.1), since these are officially endorsed by the South African Department of Health and numerous professional societies linked to food and nutrition. In addition, for this specific project, the group reached consensus to select criteria which would address micronutrient deficiencies of public health importance in South Africa with focus on the most vulnerable, and which could be incorporated in a sustainable home-based food-production approach.

Box 5.1: South African food-based dietary guidelines

- Enjoy a variety of foods
- Be active
- Drink lots of clean, safe water
- Make starchy foods the basis of most meals
- Eat dry beans, split peas, lentils and soya regularly
- Chicken, fish, meat, milk or eggs can be eaten daily
- Eat plenty of vegetables and fruit every day
- Eat fats sparingly
- Use salt sparingly
- Use food and drinks containing sugar sparingly and not between meals
- If you drink alcohol, drink it sensibly

Originally it was decided to focus the criteria on non-staples, because staples are considered *core* foods as opposed to *peripheral* food (Kittler et al., 2008), because the diets of the rural poor are cereal-based (and hence do not lack cereals; see Chapter 3) and since staple grain meal for home consumption is mostly purchased (as opposed to home-produced / home-cultivated; Chapter 3). Following an extensive debate during the reference group meeting, it was, however, decided to be rather inclusive than exclusive, and thereby also include cereals in the recommendations. Brainstorming regarding appropriate criteria for selection of non-staples resulted in the guidelines presented in Box 5.2.

Box 5.2: Workshop guidelines for the identification of non-staple foods for addressing the nutritional gaps of the rural poor

The recommended foods should

1. address nutritional gaps taking into consideration
    - the dietary requirements of target groups
    - the prevalence of micronutrient malnutrition specifically in children
    - obesity and chronic disease prevalence in adults
    - immune compromised groups
2. take regional differences into account
3. be agro-ecologically viable and adaptable (considering climatic requirements)
4. be socio-culturally acceptable (regional, what they eat currently, awareness, knowledge, Indigenous Knowledge Systems)
5. be affordable (related to socio-economic status; representing "best nutritional value for money").

In addition the following should be taken into account:

6. Do support systems from Government and non-government organisations exist for the agronomic component?
7. Are support systems for nutrition education and promotion in place?
8. The micronutrients of public health importance with respect to malnutrition are vitamin A, iron and zinc.
9. A continuous supply of planting material (seed systems / high quality seeds / seedlings / farming system) needs to be available and affordable.

During the workshop the following additional points were made by participants:

- The target population should be defined clearly. If the criterion of poor is used it needs to be defined by using demographic composition and social structure, e.g. household size, age and gender structure. The use of Adult Equivalent (ADEQ) could be considered. (This is an aggregate indicator for a household size. It is used mostly in analyses of household attributes as a substitute for the straightforward household size or simply the number of adults in a household since both these can give inaccurate indications. The approach is using weights that count as 1.0 for the first adult, 0.7 for the second and subsequent adults and 0.5 for each child under 15)
- The quantities needed to produce sufficient amounts of the key nutrients for a household should be included in the consideration of the criteria.
- Although a balanced and varied diet is always the aim it was suggested that vitamin A should be 1st line of approach due to the high prevalence of marginal vitamin A deficiency.
- Focus should be on recognised poverty nodes. These are areas know to perform poorly in terms of the health indicators.
- A distinction should be made between nutrition security and food security. The idea of moving beyond food and bringing in nutrition security in very specific target populations should be the focus.

The workshop output (guidelines / criteria) and inputs made by the project reference group resulted in an evaluation rubric, which not only included details within each of the three focus areas (nutrition-, food behaviour-related and agronomic considerations), but also a food list (table 5.6).

5.5.2 Conclusion

Taking into account the criteria and guidelines developed during the project workshop and by project collaborators (see above and table 5.6), the following reflects recommendations for future project(s):

- The project should not focus on staple foods, as staple foods are mostly purchased. The procurement of these foods in fortified form is supported.

- The project should focus on the production of fruit and vegetables to supplement the cereal-based diet. The focus should be on those fruit and vegetables that will address the micronutrient deficiencies in the rural poor, particularly vitamin A, and zinc.

- In particular, considering that two in three children were shown to be vitamin A deficient, the main focus should be on fruit and vegetables that are a good source of vitamin A. These include the dark yellow / orange fruit (for example mango and pawpaw) and vegetables (or example butternut, pumpkin, carrot and orange sweetpotato) and dark-green leafy vegetables (for example spinach). A variety of such fruit and vegetables must be planted to ensure year-round availability. Wild-growing leafy vegetables should supplement the locally produced spinach, particularly as spinach is a cool weather crop whereas most wild growing leafy vegetables grow in summer. Many of the vitamin A rich fruit and vegetables may be unfamiliar to the rural households – local production should thus be accompanied by nutrition education and promotion to ensure optimal adoption.

- Plant foods in general are not excellent sources of iron, but green leafy vegetables and legumes can contribute towards dietary iron intake. Recent research has demonstrated the significant contribution of African green leafy vegetables. It may thus be worthwhile to investigate the potential contribution of these crops considering their favourable agronomic properties (Uusiku et al., 2010).

- The important contribution of animal source foods, e.g. poultry and eggs, should not be underestimated. Recent studies clearly demonstrated the valuable contribution of this source of food to address specific nutritional needs and deficiencies (Grillenberger et al., 2006; Allen et al., 2011).

- The project should target its recommendations on areas where local food production is already practiced. The households should be encouraged to plant the above-mentioned fruit and vegetables in addition to any existing crops that they are planting – they should not replace the existing crops. The potential effect of this recommendation on resources (e.g. time and water) should be kept in mind.

Table 5.6: List of foods for possible further investigation and criteria for evaluating these foods

List of foods				Criteria										
				Nutrition-related considerations				Food behaviour-related considerations			Production considerations			
				Nutrient content			Availability of support systems for nutrition promotion	Frequency of consumption	Acceptability	Affordability	Animal husbandry	Crop cultivation	Water availability	Farming / home gardening systems
				Vitamin A / β-carotene	Iron	Zinc								
Animal source foods	Red meat / flesh foods (Mutton / goat / beef / pork)													
	Poultry													
	Eggs													
	Milk													
Vitamin A and mineral rich vegetables and fruits	Yellow / orange vegetables		Butternut											
			Pumpkin											
			Carrot											
			Orange sweet potato											
	Dark green leafy vegetables (DGLV)	From the wild (African leafy vegetables))	Amaranth											
			Vigna (Cowpea)											
			Corchorus (Jute)											
			Cleome (Spiderplant)											
			Citrillus (Bitter watermelon)											
Vitamin A and mineral rich vegetables and fruit	Dark green leafy vegetables (DGLV)	From the wild (African leafy vegetables)	*Cucurbita* (Pumpkin)											
			Solanum (Black nightshade)											
			Brassica rapa (Chinese cabbage)											

List of foods				Criteria										
				Nutrition-related considerations				Food behaviour-related considerations			Production considerations			
				Nutrient content			Availability of support systems for nutrition promotion	Frequency of consumption	Acceptability	Affordability	Animal husbandry	Crop cultivation	Water availability	Farming / home gardening systems
				Vitamin A / β-carotene	Iron	Zinc								
			Other: *Bidens* (black jack)											
		Home-grown	Spinach											
			Swiss chard											
			Pumpkin											
			Beetroot											
			Sweetpotato											
			Other, e.g. kale, beetroot leaves, okra, endive. fenugreek, watercress											

List of foods			Criteria										
			Nutrition-related considerations				Food behaviour-related considerations			Production considerations			
			Nutrient content			Availability of support systems for nutrition promotion	Frequency of consumption	Acceptability	Affordability	Animal husbandry	Crop cultivation	Water availability	Farming / home gardening systems
			Vitamin A / β-carotene	Iron	Zinc								
Vitamin A and mineral rich vegetables and fruit	Non-leafy vegetables	Green pepper											
	Yellow / orange fruit (excl citrus fruit)	Apricot											
		Mango											
		Melon, orange-fleshed											
		Peach, yellow											
		Loquat											
		Plum											
		Paw-paw											
Legumes	Vigna (Cowpea)												
	Bambara and other groundnuts												
	Beans, dry												
Staples	Maize												
	Sorghum												
	Other:												
Control	Cabbage												

5.6 NUTRIENT CONTENT OF SELECTED FOOD PRODUCTS

5.6.1 Brief overview of food composition data

5.6.1.1 General considerations

Dietary evaluation (understood to be the interpretation / judging of the diet quality of food intake data) is dependent on many factors. Figure 5.1 is a graphical summary of part of the bigger picture underlying the evaluation of dietary intake. From the figure it is apparent that the validity of a dietary evaluation depends not only on the accuracy of the food consumption estimates (i.e. the dietary assessment technique) and the appropriate use of dietary standards (see above), but also on the food composition data.

This overview specifically deals with food composition databases (highlighted in the figure), since this is the most common, albeit indirect, way of obtaining nutrient-based data in practice and community-based research settings, and is sometimes called the “foundation of dietetic practice and research” (Pennington et al., 2007). It is, however, acknowledged that in other, specialized settings (such a feeding trials or metabolic ward studies) direct chemical analysis of duplicate portions is also done.

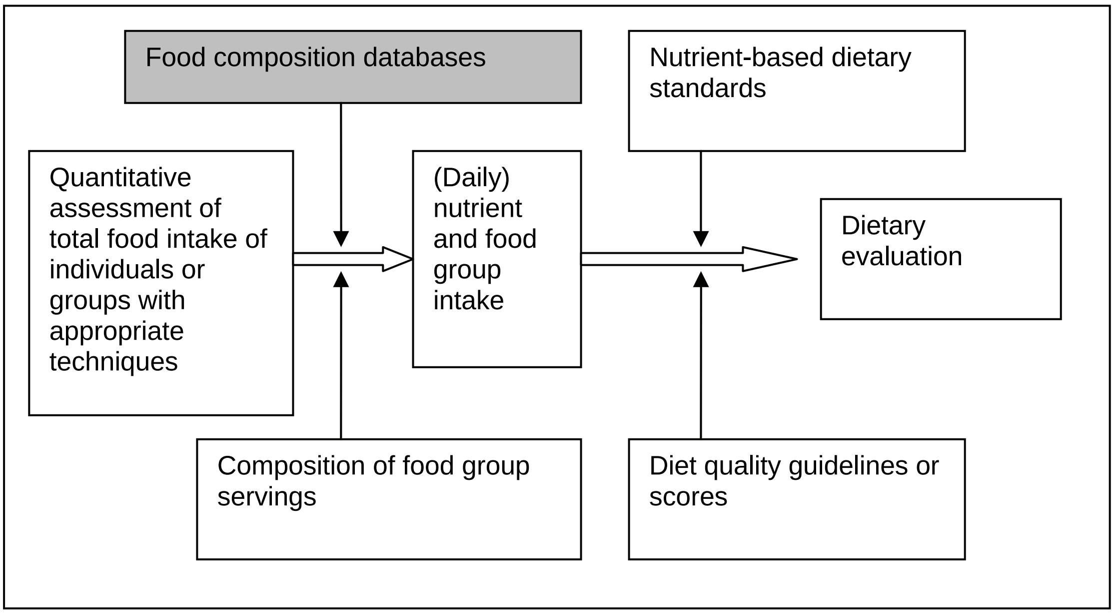

Figure 5.1: Food composition in the context of dietary evaluation (adapted from Pennington et al., 2007)

A high quality food composition database can be defined as an acceptable approximation of the real nutrient (and non-nutrient) content of food or, in the words of Southgate and Greenfield, “the true test of quality of a value is the accuracy with which it predicts the composition of another equal representative sample of the food” (cited by Joyanes & Lema, 2006).

Food composition databases can be in the form of (paper-based) tables, which express the composition of food items or recipes per weight (e.g. 100 g) or serving size of the item, or, more commonly, the inclusion of this information in computerized dietary analysis systems. Regardless of the format, the core and primary consideration when selecting a food composition database should be (at least from a scientific perspective) the data and the quality thereof in the database as such (i.e.

apart from considerations related to software operation, system output [user-friendliness], cost, etc.). The following are some of the issues and criteria that are used in relation to the quality of food composition databases in general and also specifically in respect of the International Network of Food Data System (INFOODS) (Burlingame, 2004; Joyanes & Lema, 2006; Pennington et al., 2007; Puwastien, 2002; Stumbo, 2008; Tsukakoshi, 2011; Wolmarans & Wentzel-Viljoen, 2008):

- Representativeness (referring on the one hand to the food itself in order to ensure year-round and nation- or region-wide mean values, and on the other hand to sampling plans, sample handling, etc.)
- Completeness (referring to inclusion of all relevant foods and food components with no missing values)
- Harmonized approach (referring to food and component identification [nomenclature and terminology], units and modes of expression, data quality and integrity [e.g. analytical methods, quality control protocols, conversion factors used for calculating energy and protein, etc.] and international exchangeability (e.g. grouping of foods, food preparation and processing)
- Documentation (referring to the sources of data so that the information is traceable).

In addition to the above, the ideal food composition database should be current and linked to the peculiarities of the dietary assessment technique, which, in turn, is validated for the target group under investigation. Yet foods are often complex chemical and physical entities in which physiologically active ingredients are not present in one pure form. They are characterised by heterogeneity and variability, which may be inherent ("natural") or due to processes in the farm to fork chain, including post-harvest, processing, storage and preparation techniques. Particular nutrients may also pose specific challenges, even though quality indices have been developed for some nutrients. Nutrients from various national databases that often show considerable variation are calcium, β-carotene and vitamin A (Burlingame, 2004; Joyanes & Lema, 2006; Pennington et al., 2007; Puwastien, 2002; Stumbo, 2008; Tsukakoshi, 2011).

Thus, information from food composition databases will never be complete (in terms of covering all foods and all food components), is subject to variability and change, and will thus remain an estimate. Compilations consequently rely heavily on a science-based best-guess or best fit decisions.

5.6.1.2 The South African situation

In spite of the availability of extensive international information, Wolmarans and Danster (2008) argue that a country-specific food composition database is necessary because of the unique dietary habits, environmental factors and fortification policy of South Africa. The "Condensed Food Composition Tables for South Africa" of 2010 is the most recent compilation by the Nutritional Intervention Research Unit of the MRC of South Africa of information from the SAFOODS (Wolmarans et al., 2010).

Not all foods included in the South African database are the result of chemical analyses. Calculations (for example to determine fatty acid content of a food and for determining the composition of recipes), imputations (i.e. using information from similar foods to estimate missing values), other food composition databases, literature and some assumptions were used for this compilation (Wolmarans & Danster, 2008; Wolmarans & Wentzel-Viljoen, 2008). In total, the condensed food composition table reports on 1472 food items grouped into 16 food groups. Information of 36 food components is provided. Overall, the compilers state that 36.9% of data has South African origin, 27.4% comes from the USA (mainly the United States of America Department of Agriculture [USDA]) and 7% from the UK. Recipe calculations make up 28.5% of the data and 0.2% comes from other sources. For each item documentation (source of information) is available and for the South African data analytical details are provided (Wolmarans et al., 2010).

FoodFinder3® is a software programme developed by the MRC to facilitate assessment of food composition. Other software programmes are also available in South Africa, e.g. “Food Fundi” and “Dietary Manager”. The former is based on earlier versions of the MRC food composition database, whereas Dietary Manager’s main source of information is the USDA Nutrient Database supplemented with South African food information from product labels. A study comparing FoodFinder3® and Dietary Manager found that the two nutrient databases did not differ significantly from each other despite using different food sources. There were, however, differences between the amounts estimated by the two programmes and chemical analyses: both programmes resulted in statistically and practically higher values than the chemical analysis for total fat, saturated fatty acids and mono-unsaturated fatty acids. FoodFinder3® produced significantly lower levels of soluble and insoluble fibre than the chemical analysis. The authors conclude that for controlled feeding trials the food composition databases are not adequate (Van der Watt et al., 2008).

It follows that the general conclusion that food composition databases provide estimates only, is also true for South Africa. In spite of this, they remain the only feasible approach in general nutrition practice and research. Ongoing food composition research is needed, and this may be particularly important for certain food components, such as the vitamin A value of plant foods.

5.6.2 Nutrient content of selected foods

Based on the recommendations of the reference group of this project, the list of selected foods (Table 5.6) represents an inclusive approach (meaning a more comprehensive rather than focussed selection of food items, at the risk of including foods that may from the outset not meet the criteria regarding nutritional value, food behaviour and production as set out above).

The nutrient content of the selected foods listed above was extracted from the South African food database (Wolmarans et al., 2010). It was decided to extract specific, project-relevant food component information from the database. The following components were chosen: energy, macronutrients (protein, fat, carbohydrate) and micronutrients (minerals: calcium, iron, zinc, copper, manganese; (pro) vitamins: β-carotene, vitamin A, thiamin, riboflavin, niacin, vitamin B_6, folate, vitamin B_{12} and vitamin C). See also Table 5.1 for descriptions of the components.

The sources of information regarding nutrient content of the individuals foods contained in the South African food composition database are given in Table 5.7 in order to show that this database meets the requirement of documentation as stated in the above introduction, and in particular to highlight for which foods local values are available. Energy and macronutrient content are given in Table 5.8, and the micronutrient content is in Table 5.9.

The nutrient content of 29 (59%) of the 50 food items listed in table 5.7 were sourced from South African data. Some of the sources are commercial and some are rather dated publications.

Table 5.7: Sources of nutrient content in the South African food composition database (Source: Wolmarans et al., 2010)

Food	Code	Source*	South African value	Comment
ANIMAL FOODS				
Mutton	4335	1.01		Nutrient content will vary greatly, depending on the grade and cut of the meat
Goat	4282	1.01		
Beef	4360	130	Yes	
Pork	4336	1.01		
Chicken, dark meat	4305	121	Yes	Without the skin
Chicken, light meat	4302	121	Yes	Without the skin
Eggs	2901	28	Yes	
Milk, whole	2718	3.02	Yes	
VEGETABLES				
Butternut	4174	3.01	Yes	
Cabbage	3704	3.01	Yes	
Carrot	3709	3.01	Yes	
Green pepper	3733	3.01	Yes	
Hubbard squash	4176	3.01	Yes	
Kale	4127	1.01		
Leaves, amaranth	3785	3.01	Yes	
Leaves, beetroot	4097	1.01		
Leaves, black jack	4210	92	Yes	
Leaves, bitter watermelon				Not included in food database
Leaves, cat's whiskers	4197	92	Yes	
Leaves, Chinese cabbage	4108	3.01	Yes	
Leaves, cowpea	4198	11	Yes	
Leaves, jute				Not included in food database
Leaves, lambquarters	4200	92	Yes	
Leaves, nettle	4202	92	Yes	
Leaves, nightshade	4203	92	Yes	
Leaves, pumpkin	4204	1.01		
Leaves, spiderplant				Not included in food database
Leaves, sow thistle	4206	92	Yes	
Leaves, sweetpotato	4208	1.01		
Orange sweetpotato	3748	1.01		Cooked value only
Pumpkin	4163	3.01	Yes	
Spinach (small leaved)	4167	1.01		
Swiss chard	4168	3.01	Yes	
FRUIT				
Apricot	3534	3.01	Yes	
Loquat	3555	1.01		

Food	Code	Source*	South African value	Comment
Mango	3556	3.01	Yes	
Melon, orange-fleshed	3541	3.01	Yes	
Paw-paw	3563	3.01	Yes	
Peach, yellow	4258	3.01	Yes	
LEGUMES				
Cowpea				Not included in food database
Peanuts	4285	1.01		
Beans, haricot, dried	3180	1.24		
Beans, sugar, dried	3206	45	Yes	
Beans, broadbeans, dried	3200	1.24		
Chick peas, dried	3187	1.24		
Lentils	3204	45	Yes	
Peas, split	3181	1.24		
Soybeans, dried	3182	1.24		
GRAINS				
Maize	4130	7	Yes	
Sorghum				Values for cooked porridge only

*1.01 – United States Department of Agriculture, Agricultural Research Service. 1998. USDA nutrient database for standard reference, release 12. Nutrient data laboratory home page. [On-line]. Available: http//www.nal.usda.goc/fnic/foodcomp

1.24 – Haytowitz DB, Matthews RH. 1986. Composition of foods: legumes and legume products. Agricultural handbook no 8-16. USDA, Washington.

3.01 – South African Department of Health. 1996. Laboratory reports with analytical data on South African vegetables and fruit (including bobotie, macaroni & cheese, and hake).

3.02 – South African Department of Health. 1997. Laboratory reports with analytical data on South African dairy products: milk and milk products.

7 – Pillsbury Brands Africa (Pty) Ltd. 1997. Nutrient composition of frozen vegetables.

11 – Fox FW. 1966. Studies on the chemical composition of foods commonly used in Southern Africa. SA Institute for Medical Research, Johannesburg.

28 – Egg Board. 1991. Laboratory report on the nutrient content of chicken eggs.

45 – Jungle Oats Company. 1990. Nutrient composition of barley, pearl wheat, oats, lentils, soup mix and dried sugar beans.

92 – Wehmeyer AS. 1986. Edible wild plants of Southern Africa. Data on the nutrient contents of over 300 species. Unpublished report for the Council for Scientific and Industrial Research, Pretoria.

121 – South African Department of Health. 1998. Laboratory reports and analytical data on South African chicken (fresh and frozen).

130 – Schönfeldt HS, Welgemoed C. 1996. Composition of South African Beef. South African Meat Board, Pretoria.

Table 5.8: Moisture, energy and macronutrient content per 100 g raw edible portion, as per South African food composition database (Source: Wolmarans et al., 2010)

Food	Code	Moisture g	Energy kJ	Protein g	Fat g	Carbohydrates g
ANIMAL FOODS						
Mutton	4335	60.7	1087	16.9	21.6	0.0
Goat	4282	75.8	436	20.6	2.3	0.0
Beef	4360	65.4	852	19.2	14.2	0.0
Pork	4336	49.8	1535	13.9	35.1	0.0
Chicken, dark meat	4305	73.5	606	19.1	7.6	0.0
Chicken, white meat	4302	74.9	491	23.0	2.7	0.0
Eggs	2901	75.0	616	12.6	10.3	1.2
Milk, whole	2718	88.0	262	3.2	3.4	4.8
VEGETABLES						
Butternut	4174	85.2	243	1.6	0.1	10.8
Cabbage	3704	91.9	136	1.5	0.1	4.3
Carrot	3709	89.2	170	0.9	0.0	6.4
Green pepper	3733	94.6	102	0.9	0.1	3.1
Hubbard squash	4176	91.2	148	0.7	0.1	6.6
Kale	4127	84.5	252	3.3	0.7	8.0
Leaves, amaranth	3785	88.6	155	2.9	0.2	1.6
Leaves, beetroot	4097	92.2	102	1.8	0.1	0.3
Leaves, black jack	4210	84.8	222	3.4	0.4	2.4
Leaves, cat's whiskers	4197	85.0	219	4.6	0.9	1.7
Leaves, Chinese cabbage	4108	94.5	87	0.9	0.1	2.2
Leaves, cowpea	4198	85.8	178	4.5	0.4	1.5
Leaves, lambquarters	4200	85.0	186	4.4	0.3	1.9
Leaves, nettle	4202	80.2	267	5.4	0.7	2.4
Leaves, nightshade	4203	82.5	243	5.3	0.4	2.2
Leaves, pumpkin	4204	92.9	108	3.2	0.4	0.4
Leaves, sow thistle	4206	89.9	131	2.2	0.5	1.2
Leaves, sweetpotato	4208	88.0	188	4.0	0.3	4.4
Orange sweetpotato	3748	72.9	446	1.7	0.1	21.3
Pumpkin	4163	91.9	126	0.8	0.1	4.7
Spinach (small leaved)	4167	91.6	124	2.9	0.4	0.8
Swiss chard	4168	89.9	130	2.7	0.2	1.6
FRUIT						
Apricot	3534	86.7	158	0.8	0.1	6.5
Loquat	3555	86.7	220	0.4	0.2	10.4
Mango	3556	81.7	303	0.6	0.2	15.3
Melon, orange-fleshed	3541	89.3	174	0.8	0.1	8.2
Paw-paw	3563	88.8	186	0.4	0.1	8.6

Food	Code	Moisture g	Energy kJ	Protein g	Fat g	Carbohydrates g
Peach, yellow	4258	85.8	235	0.8	0.1	10.9
LEGUMES						
Peanuts	4285	6.5	2533	25.8	49.2	7.6
Beans, haricot, dried	3180	12.4	1459	22.3	1.3	35.5
Beans, sugar, dried	3206	12.4	1451	16.9	1.3	46.2
Beans, broadbeans, dried	3200	11.0	1490	26.1	1.5	35.4
Chick peas, dried	3187	11.5	1582	19.3	6.0	46.0
Lentils	3204	9.9	1503	25.5	0.7	40.7
Peas, split	3181	11.3	1489	24.6	1.2	34.9
Soya beans, dried	3182	8.5	1870	36.5	19.9	17.7
GRAINS						
Maize	4130	76.0	422	3.2	1.2	16.3

Table 5.8 shows that per 100 g raw edible portion the foods of animal origin and legumes have the highest concentration of protein, ranging from 3.2 g for milk to 36.5 g for soybeans. In this context the concept of biological value becomes pertinent, since the proteins of animal origin typically have more complete amino acid profiles, yet combining proteins with lower biological values can result in complementation. Furthermore, typical quantities consumed (based on cost, dietary habits, life stage, etc.) and the weight changes in the food during preparation (e.g. cooking) need to be kept in mind. These considerations play a role when interpreting the 3.2 g of protein in 100 g raw edible maize. Peanuts have a high fat and therefore energy content. Within the group of orange / yellow vegetables, orange sweetpotato has considerably higher carbohydrate and energy content.

As was the case for table 5.8, the information of table 5.9 needs to be interpreted with caution. A simple ranking of food items based on nutrient content per 100 g raw edible amount of the food can be misleading. Fundamental nutrition and food consumption knowledge affects the usefulness of the data presented. For example, in the case of iron content, the values for dried soybeans or nightshade leaves must be seen in the context of typical cooked amounts consumed by the vulnerable target group, apart from the issues related to bioavailability associated with iron in the non-haeme (plant-based) form. Leaves have a high content of oxalates, phytates and polyphenols which inhibit non-haeme iron absorption. Because of the low bio-availability of the non-haeme iron in plant foods, its potential towards reducing iron deficiency has been questioned and agricultural interventions to increase the supply and intake of iron from plant foods are not popular (De Pee et al., 1996; Ruel, 2001). Vitamin C enhances the absorption of non-haeme iron; vitamin C is associated with fresh fruit and vegetables. The table shows that higher concentrations of zinc per 100 g raw edible foods are found in animal-source items and legumes. Preformed vitamin A is restricted to foods of animal origin (not visible from the table) whereas β-carotene is found in plant foods, particularly those that are deep-orange or dark green leaved.

Table 5.9: Micronutrient content per 100 g raw edible portion – as per South African food composition database (Source: Wolmarans et al., 2010; Kruger et al., 1998)

Food	Code	Calcium	Iron	Mg	Zinc	Copper	Mn	β-carotene	Vit A	Thiamin	Riboflavin	Niacin	Vit B_6	Folate	Vit B_{12}	Vit C
		mg	mg	mg	mg	mg	µg	µg *	µg RE	mg	mg	mg	mg	µg	µg	mg
ANIMAL FOODS																
Mutton	4335	12	1.6	22	3.33	0.10	19		0	0.12	0.22	6.1	0.130	18	2.4	0
Goat	4282	13	2.8	0	4.00	0.26	38		0	0.11	0.49	3.8	0.000	5	1.1	0
Beef	4360	13	0.7	19	3.42	0.32	17		0	0.13	0.08	5.4	0.212	10	1.0	0
Pork	4336	19	0.7	13	1.59	0.06	11		3	0.60	0.21	3.8	0.284	4	0.6	tr
Chicken, dark meat	4305	7	1.3	23	2.20	0.07	70		24	0.14	0.07	3.4	0.180	1	0.4	3
Chicken, white meat	4302	14	1.1	28	0.74	0.06	90		8	0.13	0.08	5.7	0.610	1	0.2	1
Eggs	2901	39	1.8	9	1.15	0.12	60		66	0.13	0.40	0.1	0.042	46	1.9	0
Milk, whole	2718	120	0.1	12	0.38	0.01	4		47	0.02	0.16	0.1	0.035	5	0.4	0.31
VEGETABLES																
Butternut	4174	13	0.4	20	0.31	0.09	100	530	128	0.07	0.02	1.6	0.110	23	0.0	12
Cabbage	3704	31	0.3	13	0.15	0.02	150	40	7	0.04	0.02	0.3	0.080	16	0.0	30
Carrot	3709	24	0.6	10	0.35	0.02	110	15900	3250	0.03	0.12	0.6	0.060	10	0.0	4
Green pepper	3733	7	0.9	10	23	0.17	120		36	0.04	0.02	0.6	0.171	5	0.0	77
Hubbard squash	4176	20	0.2	16	0.16	0.50	70	2359	396	0.03	0.02	1.3	0.100	12	0.0	11
Kale	4127	135	1.7	34	0.44	0.29	774	5315	890	0.11	0.13	1.0	0.271	29	0.0	120
Leaves, amaranth	3785	260	4.8	128	1.51	0.20	3240	1798	326	0.01	0.10	1.0	0.180	64	0.0	46
Leaves, beetroot	4097	119	3.3	72	0.38	0.19	391	3658	610	0.10	0.22	0.4	0.106	15	0.0	30
Leaves, black jack	4210	175	6.0	135	0.91	0.58	1619	5900	983	0.08	0.18	0.7	0.352	351	0.0	23
Leaves, cat's whiskers	4197	189	2.6	76	0.76	0.42	1598	7183	1197	0.10	0.12	1.3	0.347	346	0.0	50
Leaves, Chinese	4108	40	0.4	7	0.14	tr	160	50	9	0.03	0.02	0.6	0.060	22	0.0	68

Food	Code	Calcium	Iron	Mg	Zinc	Copper	Mn	β-carotene	Vit A	Thiamin	Riboflavin	Niacin	Vit B_6	Folate	Vit B_{12}	Vit C
		mg	mg	mg	mg	mg	µg	µg *	µg RE	mg	mg	mg	mg	µg	µg	mg
cabbage																
Leaves, cowpea	4198	188	2.7	60	0.40	0.27	707	592	99	0.49	0.24	1.6	0.246	141	0.0	50
Leaves, jute																
Leaves, lambquarters	4200	226	6.1	155	1.36	0.40	782	5490	915	0.03	0.31	0.6	0.274	30	0.0	31
Leaves, nettle	4202	668	7.2	133	0.69	0.30	2109	6070	1012	0.04	0.31	1.1	0.459	457	0.0	5
Leaves, nightshade	4203	278	8.5	84	1.16	0.36	1864	6380	1063	0.10	0.32	1.1	0.405	404	0.0	22
Leaves, pumpkin	4204	39	2.2	38	0.20	0.13	355	1164	194	0.09	0.13	0.9	0.207	36	0.0	11
Leaves, sow thistle	4206	193	7.1	51	0.90	0.25	1076	5900	983	0.03	0.11	0.4	0.234	233	0.0	25
Leaves, sweetpotato	4208	37	1.0	61	0.29	0.04	256	618	103	0.16	0.35	1.1	0.190	80	0.0	11
Orange sweetpotato	3748	28	0.5	20	0.29	0.21	560	13092	2182	0.07	0.13	0.6	0.241	23	0.0	25
Pumpkin	4163	18	0.4	12	0.24	0.09	110	920	156	0.02	0.02	0.6	0.100	4	0.0	8
Spinach (small leaved)	4167	99	2.7	79	0.53	0.13	897	4009	672	0.08	0.19	0.7	0.195	194	0.0	28
Swiss chard	4168	117	4.4	78	0.73	0.17	1680	2790	468	0.03	0.10	0.6	0.080	52	0.0	24
FRUIT																
Apricot	3534	15	0.5	11	0.16	0.08	77	405	68	0.01	0.02	0.5	0.040	tr	0.0	4
Loquat	3555	16	0.3	13	0.05	0.04	148	439	99	0.02	0.02	0.2	0.100	14	0.0	1
Mango	3556	9	0.2	10	0.07	0.07	140	390	66	0.06	0.03	0.7	0.070	40	0.0	31
Melon, orange-fleshed	3541	11	0.4	13	0.10	0.10	70	690	116	0.04	0.01	0.7	0.040	22	0.0	39
Paw-paw	3563	24	0.1	18	0.04	0.05	22	97**	101	0.03	0.01	0.3	0.006	14	0.0	87
Peach, yellow	4258	6	0.3	7	0.09	0.07	50	40	9	0.03	0.03	0.7	0.020	2	0.0	13

Food	Code	Calcium	Iron	Mg	Zinc	Copper	Mn	β-carotene	Vit A	Thiamin	Riboflavin	Niacin	Vit B_6	Folate	Vit B_{12}	Vit C
		mg	mg	mg	mg	mg	µg	µg *	µg RE	mg	mg	mg	mg	µg	µg	mg
LEGUMES																
Peanuts	4285	92	4.6	168	3.27	1.14	1934		0	0.64	0.14	12.1	0.348	240	0	0
Beans, haricot, dried	3180	155	6.4	173	2.54	0.88	1310		0	0.65	0.23	2.1	0.437	370	0	3
Beans, sugar, dried	3206	85	5.9	164	2.54	0.88	1310		0	0.45	0.13	2.5	0.437	370	0	3
Beans, broad, dried	3200	103	6.7	192	3.14	0.82	1630		5	0.56	0.33	2.8	0.366	423	0	1
Chick peas, dried	3187	105	6.2	115	3.43	0.85	2200		7	0.48	0.21	1.5	0.533	557	0	4
Lentils	3204	80	6.9	81	-	-	-		6	0.37	0.22	2.0	-	-	-	-
Peas, split	3181	55	4.4	115	3.01	0.87	1391		15	0.73	0.22	2.9	0.174	274	0	2
Soya beans, dried	3182	277	15.7	280	4.89	1.66	2520		2	0.87	0.87	1.6	0.377	375	0	6
GRAINS																
Maize	4130	2	0.5	37	0.45	0.05	161		28	0.20	0.06	1.7	0.005	46	0.0	7

* The South African food composition data base (Kruger et al., 1998) does not contain β-carotene values for those foods that have missing values. It can however be assumed that the values for animal foods will be zero, as β-carotene is found in plant foods. As β-carotene is the precursor for vitamin A, it can further be assumed that for those legumes with zero vitamin A content, the β-carotene content will also be zero.

** plus 1019 µg cryptoxanthin

tr – trace

Values indicated with a slash are missing values in the food composition database

The vitamin A content of food in the South African food composition database is expressed as µg retinol equivalents (RE) using the conversion factors of 1 µg retinol = 6 µg β-carotene or 12 µg cryptoxanthin or 12 µg α-carotene (Wolmarans et al., 2010). The Dietary Reference Intakes (DRI) for the United States and Canada the U.S. Institute of Medicine (IOM, 2001) introduced the term "retinol activity equivalent" (RAE) to replace the RE used by FAO/WHO (2001) to take into account new research on vitamin A activity (bioefficacy) of carotenoids. The IOM considers carotenoid bioefficacy in mixed foods eaten by healthy people in developed countries to be half the required amount set by FAO/WHO, and uses the following vitamin A equivalency factors for provitamin A carotenoids from mixed foods, namely, 1 µg RAE is equivalent to 1 µg of preformed retinol, 2 µg of supplemental β-carotene in oil, 12 µg of β-carotene or 24 µg of other provitamin A carotenoids such as α-carotene, γ -carotene, and β-cryptoxanthin (IOM, 2001). The most important provitamin A carotenoid is β-carotene, both in terms of its bioactivity and widespread occurrence. The RAE was defined on the basis of relatively few studies and the absorption and conversion of β-carotene from different foods vary up to five-fold. Therefore, estimates of conversion factors are still approximations and may change as new information becomes available (Hess et al., 2005).

The carotenoid composition and the content of provitamin A carotenoids in plant foods vary widely and are affected by factors such as variety or cultivar; part of the plant consumed; stage of maturity; geographic site of production or climate (tropical climate favours carotenoid biosynthesis); harvesting and post-harvest handling conditions; food preparation/processing methods and storage (Rodriguez-Amaya, 1997; 1999).

5.6.3 Composition / nutritional value of orange sweetpotato, dark green leafy vegetables and other South African foods

5.6.3.1 Orange sweetpotato

Sweetpotato most commonly consumed in South Africa is white-fleshed. However, there is a wide range of sweetpotato varieties, and the colour of sweetpotato may range from cream, yellow, yellow-orange and dark-orange. The colour is directly related to β-carotene content, and colour intensity may therefore be used as an indicator of provitamin A value (Takahata et al., 1993). Sweetpotato with a cream-coloured flesh contains very little in terms of β-carotene, whereas the dark orange-fleshed varieties contain significant amounts of β-carotene. Orange-fleshed varieties of sweetpotato offer one of the highest sources of naturally occurring β-carotene. A target breeding level of 7500 µg β-carotene per 100 g has been proposed for populations where sweetpotato is the sole source of β-carotene, and 3700 µg β-carotene per 100 g if a mixed diet is eaten (Nestel et al., 2006).

A limitation of the South African food composition database is the fact that only one vitamin A value is given for orange sweetpotato, and this value is based on American values.

Laurie (2010) determined the nutrient content for nine varieties of orange sweetpotato, of which each was cultivated at four geographical sites in South Africa. The mean and standard deviation for the nutrient content of the fresh roots over the four geographical sites per variety is given in table 5.10. The trans-β-carotene content of the nine orange sweetpotato varieties ranged from 5100 to 16500 µg per 100 g. The β-carotene in orange sweetpotato is almost exclusively in the form of trans- β-carotene (Van Jaarsveld et al., 2006). The β-carotene values reported by Laurie (2010) were significantly higher than those reported by Leighton (2006), who reported 10112 µg per 100 g for Resisto and 4212 µg per 100 g for W-119. The average nutrient content (other than β-carotene) for four orange sweetpotato varieties as reported by Leighton (2006) is given in table 5.11. When comparing the values given in tables 7 and 8, the variation in nutrient content is clear. For example, the calcium values reported by Leighton (2006) are nearly double the calcium value reported by Laurie (2010).

Table 5.10: Mean content of selected nutrients in nine orange sweetpotato varieties (per 100 g raw)

Variety	*trans*-β-carotene (µg/100 g)	Potassium (mg/100 g)	Calcium (mg/100 g)	Phosphorous (mg/100 g)	Magnesium (mg/100 g)	Iron (mg/100 g)	Zinc (mg/100 g)	Dry matter (%)
Resisto	16 500 ± 35	272 ± 45	63 ± 1	45 ± 7	30 ± 3	0.91 ± 0.33	0.60 ± 0.13	27.3 ± 2.1
Khano	14 000 ± 13	314 ± 65	55 ± 10	46 ± 9	37 ± 3	0.81 ± 0.23	0.64 ± 0.12	22.4 ± 2.6
2001-5-2	11 800 ± 8	234 ± 28	53 ± 5	33 ± 1	26 ± 3	0.80 ± 0.37	0.67 ± 0.13	23.9 ± 2.1
W-119	10 500 ± 16	263 ± 50	63 ± 7	42 ± 9	31 ± 6	1.26 ± 0.55	0.60 ± 0.17	28.7 ± 2.9
Beauregard	9 600 ± 14	249 ± 26	49 ± 2	30 ± 3	21 ± 3	0.76 ± 0.46	0.69 ± 0.23	19.7 ± 2.9
1999-1-7	9 600 ± 15	297 ± 37	48 ± 17	43 ± 7	29 ± 6	1.15 ± 0.35	0.56 ± 0.14	25.1 ± 1.9
Excel	5 200 ± 6	291 ± 45	52 ± 5	43 ± 5	29 ± 1	0.81 ± 0.33	0.64 ± 0.19	26.7 ± 2.4
Serolane	5 100 ± 7	334 ± 62	54 ± 8	51 ± 10	33 ± 3	0.99 ± 0.42	0.62 ± 0.22	30.5 ±3.7
Impilo	5 100 ± 17	286 ± 35	51 ± 4	45 ± 3	27 ± 3	1.17 ± 0.45	0.60 ± 0.15	23.1 ±1.0
Mean	9 100	282	54	42	29	0.96	0.62	25.2

Source: Laurie, 2010

Table 5.11: Average nutrient content for four orange sweetpotato varieties combined (per 100 g raw)

Nutrient	**Unit**	Mean ± SEM
Vitamin C	mg	7.07 ± 1.55
Calcium	mg	101 ± 8.01
Magnesium	mg	19.3 ± 2.60
Phosphorous	mg	57.7 ± 4.30
Potassium	mg	324 ± 25.5
Iron	mg	0.62 ± 0.12
Manganese	mg	0.38 ± 0.20
Zinc	mg	0.37 ± 0.03*
Copper	mg	0.12 ± 0.05

Source: Leighton 2006
* these values have been corrected in a personal communication with SM Laurie (see Laurie 2010, p 23)

5.6.3.2 Dark green leafy vegetables

The potential role of dark green leafy vegetables in addressing common micronutrient deficiencies of developing countries, including South Africa, has led to numerous individual studies into the composition of these, particularly the indigenous, indigenized or traditional forms of African leafy vegetables. Uusiku et al. (2010) reviewed the nutritional value (referring to energy, protein, fibre, fat, carbohydrates, vitamin A, vitamin C, riboflavin, folate, calcium, iron, magnesium, zinc and other non-nutrient components) of selected leafy vegetables of sub-Saharan Africa as a whole. On the other hand, Schönfeldt and Pretorius (2011) published the proximate composition, energy, iron, zinc, magnesium, calcium, phosphorus, total β-carotene, trans β-carotene and vitamin B_2 content of raw and cooked leaves of *Amaranthus tricolor* (misbredie), *Cucuribita maxima* (pumpkin), *Vigna unguiculata* (cowpea), *Cleome gynandra* (cat's whiskers) and *Corchorus tridens* (wild jute).

Van Jaarsveld, Faber and Van Heerden (2011) investigated the proximate analysis, mineral (calcium, magnesium, phosphorus, sodium, potassium, copper, zinc, iron and manganese) and vitamin (thiamine, riboflavin, folate, vitamin C, total β-carotene, all-*trans*-β-carotene and vitamin A) content of the leaves of Chinese cabbage *(Brassica rapa* L. subsp. *Chinensis)*, black nightshade *(Solanum retroflexum* Dun), amaranth *(Amaranthus cruentus* L.), Jew's mallow *(Corchorus olitorius* L.), cowpeas *(Vigna unguiculata* L. Walp.), pumpkin *(Cucurbita maxima),* bitter watermelon *(Citrillus lanatus* (Thunberg) Matsum. subsp. *Lanatus) and s*piderplant *(Cleome gynandra* L.). The β-carotene values reported by van Jaarsveld and co-workers (2011) was considerably higher and the vitamin C content lower than the values in the South African food composition database (Wolmarans et al., 2010).

To illustrate the variation in reported nutrient content for foods, selected nutrient content of African leafy vegetables as reported by Van Jaarsveld and co-workers (2011) and Schönfeldt and Pretorius (2011) is given in Table 5.12. Schönfeldt and Pretorius (2011) reported considerably higher values for iron content and lower values for β-carotene content. Comparing nutrient content of leaves from different data sources should be done cautiously as the nutrient content of raw plant foods vary widely and is affected by factors such as variety or cultivar; part of the plant consumed; stage of maturity; geographic site of production or climate; harvesting and post-harvest handling conditions; and storage.

Table 5.12: Selected micronutrient content of African leafy vegetables (per 100 g raw)

	Moisture (g)	Calcium (mg)	Magnesium (mg)	Zinc (mg)	Iron (mg))	β-carotene ((µg)	Vitamin C (mg)
Van Jaarsveld et al., (2011)							
Amaranthus cruentus L.	82.0	443	242	0.70	5.1	7138	2
Cleome gynandra	87.5	232	76	1.04	2.1	5936	2
Corchorus olitorius	79.6	310	87	0.57	3.6	4307	1
Cucurbita maxima	85.6	177	67	0.75	9.2	4247	2
Vigna unguiculata	82.4	398	62	0.42	4.7	7031	9
Brassica rapa	92.2	152	42	0.30	1.4	3593	8
Solanum retroflexum	89.5	199	92	0.56	7.2	5566	5
Citrillus lanatus	81.3	212	59	0.74	6.4	4956	10
Schönfeldt and Pretorius (2011)							
Amaranthus tricolor	89.9	232	141	0.8	16.2	1601	-
Cleome gynandra	84.2	393	146	1.0	14.3	4117	-
Corchorus tridens	81.0	585	81	0.8	6.3	3663	
Cucurbita maxima	87.3	383	142	0.9	15.9	1695	-
Vigna unguiculata	87.6	221	55	0.5	3.9	2249	-

5.6.3.3 Other South African foods

Against the backdrop of the increasing realization that the nutrient content of food is significantly affected by cultivar, variety or breed, the acknowledgement of the importance of agro- and food-biodiversity (Stadlmayr et al., 2011), and constant changes in the food industry, more and more South African food composition studies are published. Examples of this are the study on the fatty acid, amino acid and mineral composition of milk from Nguni and local crossbred cows (Mapekula et al., 2011). Also studies focussing specifically on the composition of South African mutton (Sainsbury et al., 2011) and lamb (Van Heerden et al., 2007) are available. The introduction of compulsory fortification of certain foodstuffs with specified micronutrients has resulted in studies measuring the actual nutrient content of these foods as purchased and consumed (Pretorius & Schönfeldt, 2011).

5.7 CONCLUSION

No single food can ensure nutritional adequacy and dietary quality. Variety, balance and moderation remain the pillars from a nutritional perspective. In addition, availability, affordability and acceptability are essential for a sustainable solution for nutrition (in)security. The list of foods compiled for further investigation represents project-specific guidance that meets project-specific criteria, focusing on potentially home-producible foods by the rural poor of South Africa.

Knowing the composition of foods consumed is essential for dietary evaluation. The South African food composition database offers an estimate of energy and nutrient content of foods, yet the limitations of the data need to be kept in mind. Refinement is ongoing in line with international harmonization and local trends. Challenges are nutrient (e.g. related to vitamin A) – and food (e.g. related to orange-fleshed sweet potato) – specific, but more and more locally relevant studies are emerging. The estimated composition of these foods is the basis for calculated nutritional water productivity, which is the topic of Chapter 6.

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CHAPTER 6

WATER USE AND NUTRITIONAL WATER PRODUCTIVITY OF SELECTED FOOD PRODUCTS

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Martin Steyn
Melvin Nyathi

6.1 INTRODUCTION

The objectives of this chapter are to:

1. Put into context the water use efficiencies and nutritional water productivities of selected unprocessed crop and animal food products of importance for human nutrition.

2. Document reliable published water use and yield data of these selected unprocessed crop and animal food products. Preference was given to local data which was used to calculate typical water use efficiency and nutritional water productivity benchmarks of these food products.

3. Identify gaps in our knowledge and highlight possible future research needs.

6.2 WATER USE

6.2.1 Introduction

Context

In this brief review, the water balance, the "colour of water", the physics of dry matter production and crop water use, and factors affecting water use efficiency (WUE) of crops are discussed. It is necessary to bear in mind that published values may differ widely, because they may be derived from crops grown in different seasons, from diverse locations where climatic conditions differ widely, or where soil type and crop management practises are very different. There are also fundamental physiological reasons why crops will vary in the efficiency with which they will utilize water. It is hoped that this brief discussion of some of the principles governing the field water balance, crop water use and dry matter production will make it clear why some caution must be exercised when considering published values of "crop water use" and "WUE", and why we would expect certain groups of crops to perform the way they do. It will also hopefully make it clear why we expect WUE to vary with environmental condition, and why it is important that factors other than water (plant nutrients, weeds, plant diseases, etc.) need to be non-limiting for optimal WUE's to be attained.

The water balance

Water is the most important compound for life and plays a major role in crop and animal production. The water that we receive on earth comes through the hydrological cycle as precipitation. Some of this infiltrates into the soil and is stored as soil water, and some flows to water bodies such as lakes, dams and rivers. The process of evaporation takes place from open water bodies, soil surfaces and through plant leaves (transpiration). In the atmosphere, water condenses and again comes back to earth as precipitation. The hydrological cycle therefore confirms that water is a renewable resource (Figure 6.1).

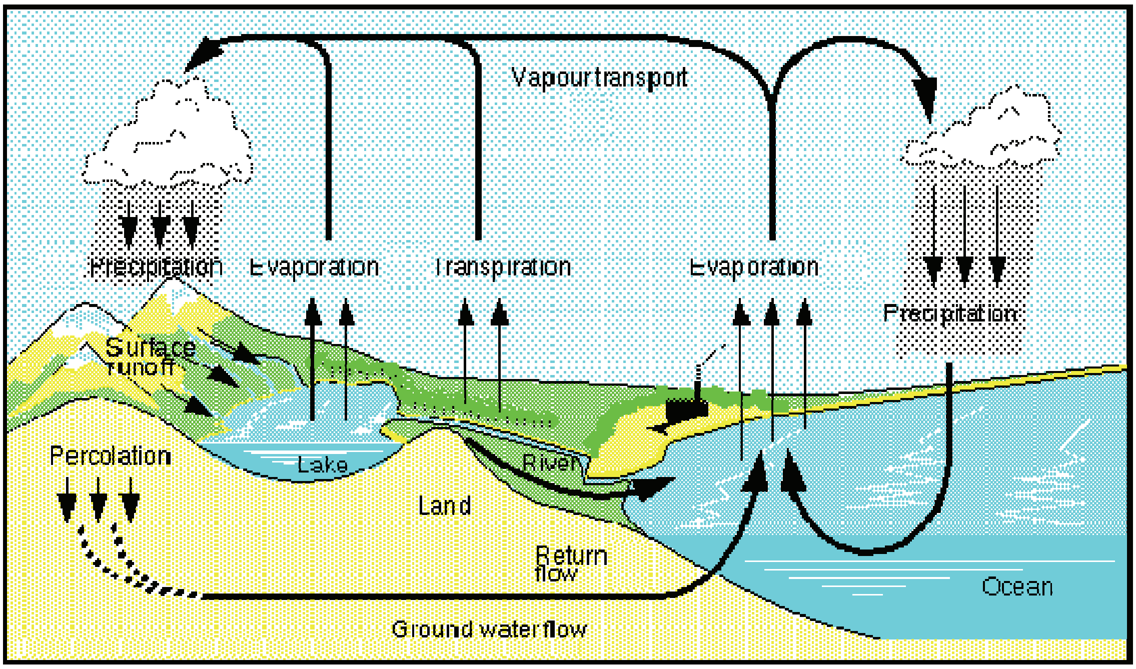

Figure 6.1: Diagram of the hydrological cycle on earth

(source: http://www.google.co.za/imgres?q=hydrological+cycle+diagram&hl)

Water that infiltrates the soil is stored as soil water and is very important in agricultural production. At field level, water inflows into the system that the farmer manages are irrigation (I), precipitation (P) and capillary rise from groundwater, while water outflows include evaporation (E), transpiration (T), runoff (R) and drainage (D) (Annandale et al., 2005; Bauman, 2007). These gains and losses can be considered the “soil water balance” components, and their management will determine how much plant available water (PAW) is stored in the soil profile for plant uptake (Figure 6.2). Farmers are faced with the challenge of reducing non-beneficial losses (R, E, D), in order to maximize the water left over for the beneficial but consumptive loss of water (T), as transpiration is directly proportional to dry matter production and crop yield (Annandale et al., 2005).

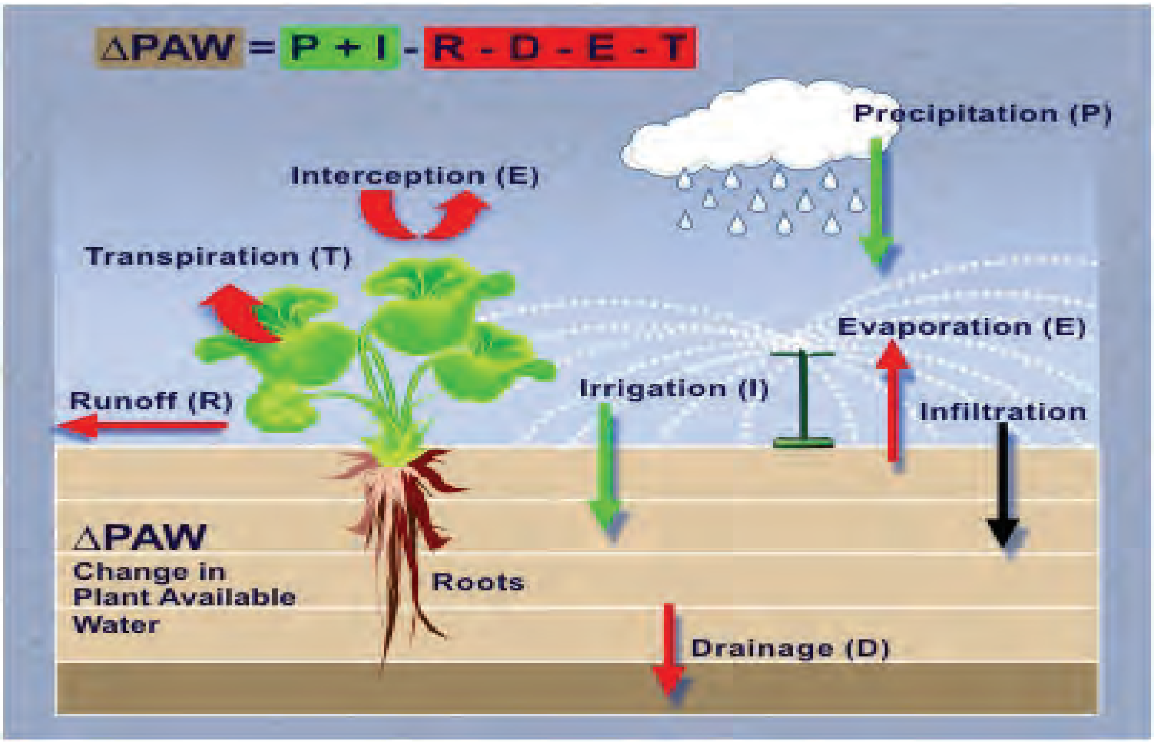

Figure 6.2: Schematic presentation of the soil water balance (Annandale et al., 2005; with permission)

It is not a trivial exercise doing a water balance and growth analysis / yield study. Many of the components of the water balance are very difficult to quantify. It is relatively easy to measure precipitation and irrigation, but surface runoff and deep drainage are notoriously hard to quantify. Not all researchers even report the change in storage in the profile between the beginning and the end of the season, and often all that is reported is water applied, which is then erroneously referred to as "water use". When the system is micro-irrigated we are then dealing with a two or three dimensional system, which is even more difficult to quantify.

Irrigation scheduling is a management intervention that can be deployed to maximize the useful loss of water and minimize the wasteful loss components of the water balance. The use of more efficient irrigation systems will also contribute greatly to more efficient water use of a particular crop.

The "colour of water"

Fresh water reaching the earth's surface through precipitation can be utilised for domestic, industrial and agricultural purposes. Recently water has been categorised into four colours – (green, blue, grey and black) which can be quite useful to consider when doing an analysis of water use. Under dryland conditions, food is produced from rainfall that replenishes soil water which is then used by growing plants *in situ.* This is referred to as **green water**. Runoff that makes its way to water bodies such as rivers, lakes, dams and aquifers is called **blue water**. Blue water can be abstracted and used for irrigation of crops, or for domestic and industrial uses, and to support the environment. Figure 6.3 illustrates the concept of green and blue water.

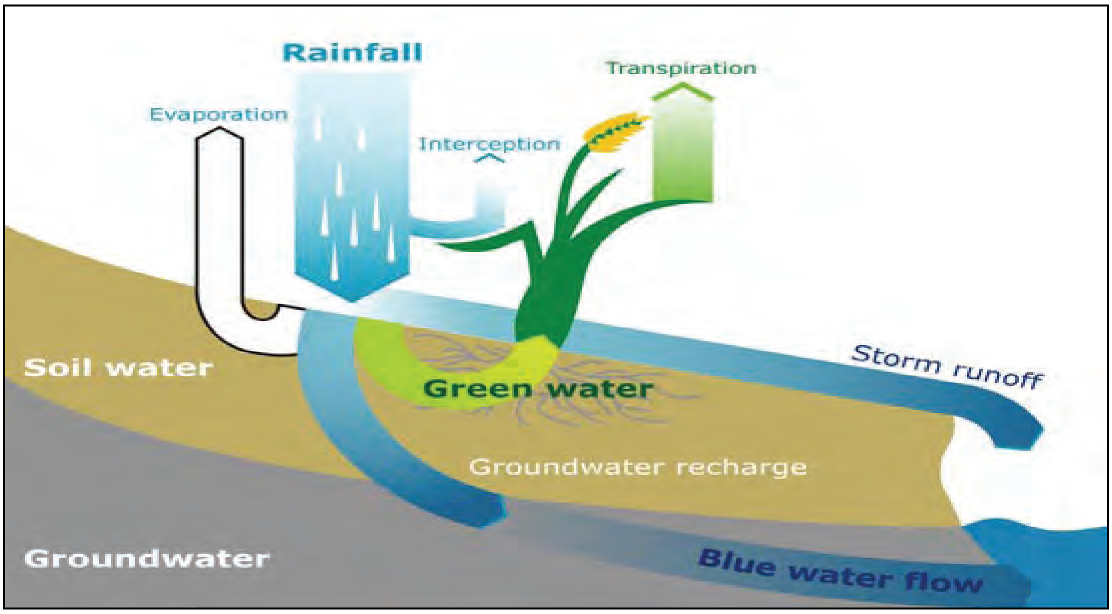

Figure 6.3: Water stored in the soil and used by plants is green water. Runoff and deep drainage, recharging the groundwater and feeding streams is blue water (Falkenmark & Rockstrom, 2004; with permission)

We also use water in our homes for bathing, washing dishes, and laundry. This soapy water is released through a network of pipes and is called **grey water**. Water that comes from our toilets is **black water**. Usually this water is not used directly for production purposes in South Africa, but is first treated through waste water treatment plants and then released to water bodies. More detailed descriptions of the “colour of water” can be found in Mekonnen and colleagues (2010a), Rodda and colleagues (2010), Stirzaker (2010) and Wegerich and Warner (2010). When we look at water use efficiencies of certain foods it will sometimes be prudent to take the “colour of water” into account.

The physics of dry matter production and crop water use

The movement of liquid water from soil, through roots, up the xylem vessels in the stems of higher plants to the leaves in the canopy, and then through stomata in the vapour phase to the atmosphere, is a very important process in crop production. It is useful to have some understanding of the physics of photosynthesis and transpiration, as this will make it clear why some plants are inherently more water efficient than others, and why the atmospheric environment plays such an important role in WUE.

Transpiration is the process by which water absorbed by roots moves through the stems to stomata where it changes to water vapour and is released to the atmosphere – a biophysical process over which the plant has some control through stomatal opening and canopy development. Direct evaporation of water from wet foliage or the soil surface, on the other hand, is a purely physical process. These two processes occur simultaneously and are called evapotranspiration. When stomata open in the presence of light, CO_2 diffuses into the leaf along a concentration gradient to produce sugars ($C_2 H_{12} O_6$) through a process called photosynthesis (Figure 6.4). There is usually a water vapour concentration gradient in the opposite direction, so the price the plant pays for photosynthesis, is transpiration (water loss).

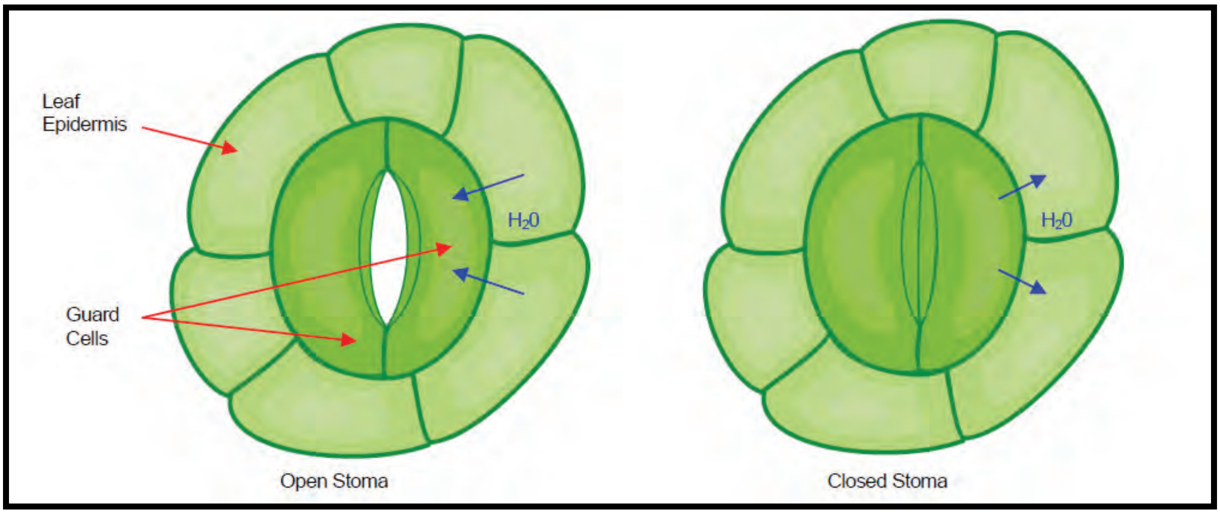

Figure 6.4: Open and closed stomata (Argus, 2009)

A leaf level analysis of these processes can be presented as follows (Campbell & Norman, 1998): First we consider dry matter production;

$$\mathbf{A_{n,\ leaf} = g_c\ (C_{ca} - C_{ci})}$$

where g_c is conductance of the boundary layer and surface (stomata) for CO_2, C_{ca} is the atmospheric CO_2 concentration and C_{ci} is the CO_2 concentration in the intercellular spaces of the leaf, and A_n is net assimilation rate (dry matter production),

Water use or transpiration (E_{leaf}) is then given by;

$$\mathbf{E_{leaf} = g_v\ (C_{vs} - C_{va})\ /\ p_a}$$

where g_v is the conductivity for vapour flow, p_a is atmospheric pressure, and the term in brackets is the vapour concentration difference between the sub-stomatal cavity which is always saturated and the outside air which is usually much drier, and is close to atmospheric vapour pressure deficit if we assume leaf temperature to be near to air temperature.
WUE_{leaf} can thus be calculated as follows:

$$\mathbf{WUE_{leaf} = A_{n\ leaf}\ /\ E_{leaf} = g_c\ p_a\ (C_{ca} - C_{ci})/\ g_v\ (e_s - e_a)}$$

where WUE_{leaf} is water use efficiency of the leaf, $e_s - e_a$ is the difference in molar fraction of water vapour between the intercellular air spaces of the leaf (e_s) and the atmosphere (e_a). The ratio g_c/g_v ranges between 0.66-0.75 but a mid range value of 0.7 is often used. Therefore, assuming leaf temperature close to air temperature, dry matter production is expressed as:

$$\mathbf{DM = kT\ /\ VPD}$$

where $k = 0.7\ p_a\ (C_{ca} - C_{ci})$ This simple equation teaches us a few important lessons:

- dry matter production cannot occur in the absence of transpiration
- production per unit water transpired in a particular location is determined by k
- WUE is inversely proportional to vapour pressure deficit (VPD or the "dryness of the atmosphere").

The value of k differs with different crop type (C3 or C4), and increases in global CO_2 levels should increase production and WUE. C4 plants (tropical grasses) have lower intercellular CO_2 concentration

(C_{ci}) compared to C3 plants, thus they produce more dry matter per unit water than C3 plants. The constant k = 0.3 for C3 crops and k = 0.7 for C4 crops. Renault and Wallender (2000) reported that C3 crops (wheat, barley, rice, potato) typically need 600 tons of water to produce one ton of dry matter, whilst C4 crops (maize, sorghum, sugarcane) only need 300 tons. This suggests that C4 plants are far more productive than C3 plants, assuming all other factors remain constant.

Kemanian and colleagues (2005) reported on the results of 11 studies that investigated growth and transpiration of wheat and barley and derived the following empirical relationship between WUE and VPD:

$$\mathbf{WUE = 4.9\ VPD^{-0.59}}$$

The effect can be illustrated with the following example: when equation 5 is applied to an arid location with a high average seasonal VPD, let's say VPD = 1 kPa, and another location that is much more humid with a much lower VPD, say an average VPD = 0.5 kPa, the calculated WUE (kg ha^{-1} mm^{-1}) would give the following results:

Arid location: WUE = 4.9 ($1^{-0.59}$) = 4.9 kg ha^{-1} mm^{-1}

Humid location: WUE = 4.9 ($0.5^{-0.59}$) = 7.4 kg ha^{-1} mm^{-1}

Another environmental factor affecting WUE is the proportion of diffuse radiation. Assimilation in diffuse radiation environments is greater than in an equivalent flux of direct radiation, while the diffuseness of the radiation has little effect on transpiration (Passioura & Angus, 2010). An analysis by Rodriguez and Sadras (2007) suggests that a 1% increase in the proportion of diffuse radiation would lead to an increase in WUE of 0.5 kg ha^{-1} mm^{-1}.

Other factors affecting water use efficiency

Apart from the biochemical pathway followed with the photosynthesis process by crops – C3, C4 or CAM (*crassulacean acid metabolism)* – there are other factors related to crop type that affect water use efficiency. Table 6.1 presents rough estimates of global water use efficiencies for groups of crops (Mekonnen et al., 2010a) that give some useful insights.

Table 6.1: Global water use efficiency of various crop groups (Mekonnen et al., 2010a)

Type of crop	Water use per ton crop (m^3 ton^{-1})	WUE (kg crop m^{-3}water)
Vegetables	300	3.33
Roots and tubers	400	2.5
Fruits	1000	1.0
Cereals	1600	0.63
Oil crops	2400	0.42
Pulses	4000	0.25

At a quick glance, vegetables seem to be far more efficient water users than any of the other crops, and the field crops, especially the oil seeds and protein rich crops are especially inefficient water users. However, the first caution is that usually crop yields are quoted without specifying ***water contents*** of the food products, so we may harvest 80 tons per hectare of tomatoes, but 90% of this is water, whereas in comparison, a seemingly low 9 ton per hectare maize crop is typically harvested at around 12% moisture content, giving roughly the same dry matter harvested.

The next important factor to consider is that of ***harvest index (HI)***. This is usually defined as the fraction of above ground dry matter that is harvested and utilized as food source. However, for root and tuber crops it is better to define HI as the fraction of total dry matter (total above and below ground, except roots) that is harvested and utilized as food.

Leafy vegetables like cabbage will have a very high harvest index, so this should make it a more efficient user of water than a crop which has to invest a lot of growth into plant parts that are not harvestable, like for example in the case of fruit trees that need branches to hang fruit from. In this regard, much improvement in crop water use efficiencies has been achieved in the past decades through crop breeding, e.g. the development of semi-dwarf wheat varieties (Passioura & Angus, 2010).

Finally, the ***composition*** of the food product harvested is extremely important. Penning de Vries (1972) derived "Production values" for the conversion of 1 g of glucose into various chemical compounds using the most efficient biochemical pathway. He calculated that 1 g of glucose could produce 0.86 g of cellulose and starch, or 0.45 g protein, or only 0.36 g lipids (fats). If we consider the composition of various foods we will see for example, that 1 g of glucose produced through photosynthesis will be able to be converted to 0.75 g of barley or rice, about 0.7 g of wheat or oats, 0.65 g of peas, 0.5 g of soybean and only 0.43 g of oil rich canola.

The Food and Agriculture Organisation (FAO) of the United Nations has published some yield and water use efficiency figures for a few specific crops that reinforce the points made above. These are presented in Tables 6.2 and 6.3.

A final comment on water use efficiency is that yields of crops are often not limited by water, but other factors such as inadequate plant nutrition, late sowing date, weeds, poor germination, diseases, insects, excessively acidic soil, soil salinity and other factors may limit yields, and under such conditions, poor WUE will result (Passioura & Angus, 2010).

Table 6.2: Yields of vegetables, root crops, fruits, cereals and oil crops (FAO, 2011)

Type of crop	Crop type	Yield (t ha^{-1})
Vegetables	Cabbage[a]; watermelon[b], pepper[c]; tomato[d]; onions[e]	25-35[a];25-35[b];20-25[c]; 45-65[d]; 35-45[e]
Roots and tubers	Potato[f]	15-25[f]
Fruits	Banana[g]; citrus[h]; grape[i]	40-60[g]; 25-40[h]; 5-10[i]
Cereals	Maize[j]; sorghum[k]; wheat[l]	6-9[j]; 3.5-5[k]; 4-6[l]
Oil crops	Groundnut[m]; soybean[n]; bean[o]; pea[p]	3.5-4.5[m]; 2.5-3.5[n]; 6-8[o]; 2-3[p]

NOTE: lower case letter superscript relates crop type to yield value

Table 6.3: WUE of vegetables, root crops, fruits, cereals and oil crops (FAO, 2011)

Type of crop	Crop type	WUE (kg ha^{-1} mm^{-1})
Vegetables	Cabbage[a]; watermelon[b], pepper[c]; tomato[d]; onions[e]	120-200[a]; 50-80[b];15-30[c];100-120[d];80-100[e]
Roots and tubers	Potato[f]	40-70[f]
Fruits	Banana[g]; citrus[h]; grape[i]	35-60[g]; 20-50[h]; 20-40[i]
Cereals	Maize[j]; sorghum[k]; wheat[l]	8-16[j]; 6-10[k]; 8-10[l]
Oil crops	Groundnut[m]; soybean[n]; bean[o]; pea[p]	6-8[m]; 4-7[n];15-20[o];6-8[p]

NOTE: lower case letter superscript relates crop type to WUE value

Figure 6.5 is an example of a dry-land wheat cropping system in Australia that was believed for three decades to be water limited, but this was shown in fact not to be the case. The horizontal distribution of reported wheat yields (solid circles) suggest that water was not the main limiter of yield in most years, as the simulated potential yields (open circles) were usually far higher in most years. When farmers learned to control root diseases through growing break crops and removing hosts for pathogens, their risk was lowered enough for them to fertilize sufficiently to attain water limited potential yields (Passioura & Angus, 2010)

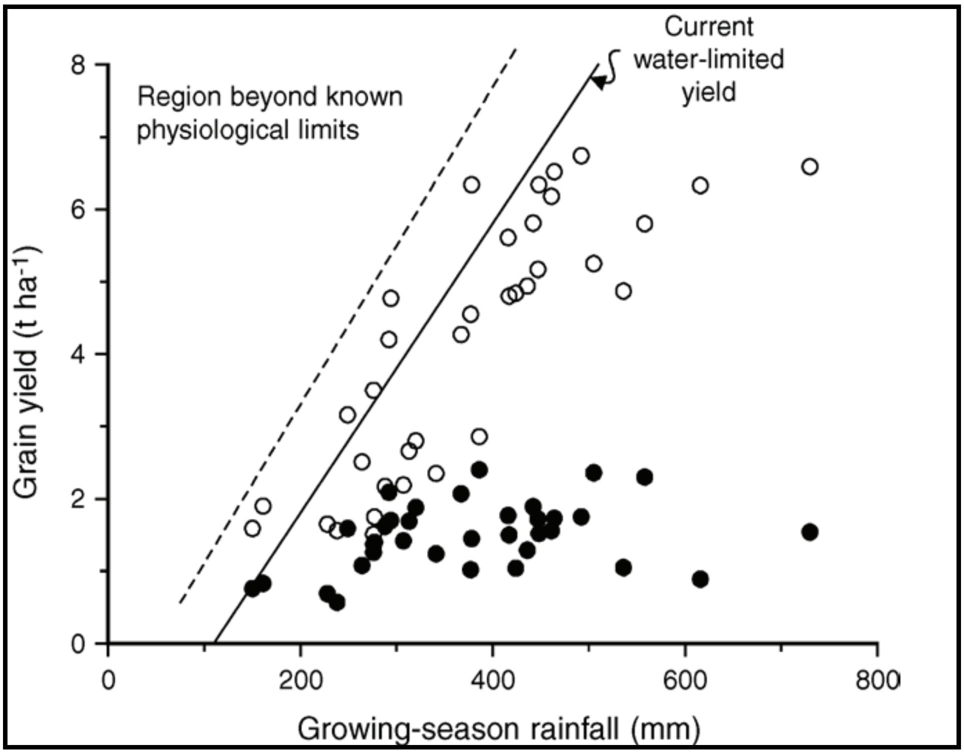

Figure 6.5: Reported (dark dots) and simulated (white dots) mean yield of wheat in the shire of Wagga Wagga. The solid line shows the upper bound of reported yields in southern Australia. Its slope is 20 kg ha^{-1} mm^{-1}. Simulation assumed that the crop was well managed, disease free, and well fed with nutrients. Farmers rarely reached the upper limit of WUE (20 kg ha^{-1} mm^{-1}). Yield is not only limited by water but other factors play a major role (Passioura & Angus, 2010).

6.2.2 Water use efficiency of selected food crops

Introduction

In spite of the fact that most of the well-known food crops have been researched for decades, local literature on water requirements of some of these crops is still very limited. Table 6.4 gives broad guidelines of yield, water use and WUE values that can be expected for some food crops under South African conditions (Hygrotech poster, undated; FAO, 2011). For the purpose of this study, food crops have been grouped into dark green leafy vegetables, yellow or orange vegetables, legumes, cereal crops, fruits and other vegetables. Published local and international research findings on the yields, water use and water use efficiencies for each of these groups are discussed.

Table 6.4: Guidelines for yields, water use and water use efficiencies that can be expected for a range of food crops under South African conditions (Hygrotech, not dated)

Product	Yield *	Water use	WUE
	t ha^{-1}	mm	kg ha^{-1} mm^{-1}
Artichoke	5-8	400	13-20
Asparagus	3-6	500	6-12
Garden beans	12-20	320	38-63
Beetroot	25-40	340	74-118
Broccoli	8-15	440	18-34
Brussels' sprouts	14-17	440	32-39
Butternut	20-30	350	57-86
Cabbage	60-80	440	136-182
Cantaloupe	25-35	420	60-83
Carrots	25-50	200	125-250
Cauliflower	30-70	440	68-159
Chinese cabbage	80	440	181
Cucumber	40-60	420	95-143
Endive	15-20	450	33-44
Garlic	15-25	450	33-56
Pumpkin	20-30	420	48-71
Spinach/Swiss chard	15-20	375	40-53
Squash	20-25	350	57-71
Sweet pepper	25-35	600	42-58
Watermelon	30-60	420	71-143

* All yields and WUE values expressed on a ***fresh mass*** basis

Water use efficiency of dark green leafy vegetables (DGLV)

Indigenous leafy vegetables provide essential nutrients to many African diets because they are highly nutritious and can adapt to local climatic conditions. The young growing points and tender leaves of plant parts are utilized in vegetable dishes and are mostly consumed as relish in African diets. Amaranthus, Black jack, cleome, and Corchorus are most widely used by rural communities of South Africa and are harvested from the wild or as weeds (van Rensburg et al., 2007).

Little local research has been published on the water use of DGLV, and no literature could be found on the water use of some species such as black jack and watercress. The Agricultural Research Council's Vegetable and Ornamental Plant Institute (ARC-VOPI), has conducted research on WUE of some of these vegetables. Beletse and others (2009) have published WUE data for amaranth (12-32 kg ha^{-1} mm^{-1}), Corchorus (7.1-10.7 kg ha^{-1} mm^{-1}), and Chinese cabbage (44-220 kg ha^{-1} mm^{-1}) from this study.

Table 6.5 summarises the local and international WUE data that could be found for DGLV's. From this table it is clear that the ranges of WUE presented for the same crops can differ markedly. For example, Beletse and others (2010), report a wide range of WUE values for cleome (18-60 kg ha^{-1} mm^{-1}), while Liyanage and colleagues (2011) report a narrower range, but with substantially lower values (7.4-10.3 kg ha^{-1} mm^{-1}) for the same crop. This clearly illustrates the effects of different experimental treatments applied, as well different growing and management conditions on published WUE figures.

Water use efficiencies for most of these crops appear to fall within the range of 10-30 kg ha^{-1} mm^{-1}, except for one report on Swiss chard / spinach (12-91 kg ha^{-1} mm^{-1}), which showed substantially higher efficiencies. These upper range values of WUE for spinach were determined from a study conducted in India and, although yields were similar, WUE's are substantially higher than the values reported locally (12-32 kg ha^{-1} mm^{-1}) by Walker (2000). This cast some doubt on the accuracy of some of the international water balance studies reported in literature.

The dry matter yields and WUE's reported here for DGLV's are on average higher than those for cereals due to higher harvest index (greater proportion of above-ground yield is edible) and it is also higher than that of legumes due to the fact that more energy is required to produce lipids and proteins, resulting in lower grain yields per unit water consumed. Table 6.5 suggests that black nightshade, cleome, and spinach are promising crops with potentially high WUE.

Table 6.5: Yield, water use, and WUE for selected dark green leafy vegetables

Product	Yield *	Water used	WUE	Source	Locality
	t ha^{-1}	mm	kg ha^{-1} mm^{-1}		
Amaranth	3.4-5.2	138-448	12-25	Beletse et al. (2009)	Roodeplaat, SA
	2.2-3.0	280	7.8-10.7	Gimplinger et al. (2007)	Not specified
	1.2-2.8	96-443	5-11.1	Beletse et al. (2012)	South Africa
Black nightshade	2.31-4.21	50-158	26.6-46.2	Ondieki et al. (2011)	Kenya
	0.4-2.4	37-242	8.1-28.8	Beletse et al. (2012)	South Africa
Cleome	2.8-8.2	232	24	Modisane et al. (2009)	South Africa
	1.8-2.14	175-288	7.4-10.3	Liyanage et al. (2011)	Nigeria
	2.4-2.8	50-158	18-60	Beletse et al. (2010)	South Africa
	3.4-4.9	71-286	12-50	Beletse et al. (2010)	South Africa
	0.6-1.1	96-443	2.0-4.8	Beletse et al. (2012)	South Africa
Chinese cabbage	1.9-5	78-260	20-24	FAO (2009)	World
	3.5-4.9	143-286	12-25	Beletse et al. (2009)	South Africa
	0.8-2.1	45-195	9-20	Beletse et al. (2012)	South Africa
Corchorus	1.7-2.4	78-258	9-23	Beletse et al. (2009)	South Africa
Cowpea (leaves)	0.1-0.25	138-258	1.1	Beletse et al. (2009)	South Africa
	0.2-1.6	117-462	2.3-5.3	Beletse et al. (2012)	South Africa
Okra	5-8	500	13	IDEA (2001)	South Africa
	11.4-15.2	500	26	Hussain et al. (2006)	Nigeria
Spinach/Swiss chard	0.61-15.8	-	55.9-90.7	Imtiyaz et al. (2009)	India
	5.1-20	425-625	12-32	Walker (2000)	South Africa

* All yields and WUE values expressed on a ***dry mass*** basis

Water use efficiency of yellow/ orange vegetables

Carrots, butternuts, sweet potato, and pumpkin are important yellow and orange vegetables in South Africa. Most of these vegetables are root tuber crops of which all the roots are harvested and consumed, although the leaves of some crops (like pumpkins) are also utilised as a vegetable. In many African diets most of these vegetables are eaten as salads or boiled. Yellow vegetables can be of great importance because they are usually rich in vitamin A. It is reported that 64% of 1-9 year old children in South Africa have a low vitamin A status, resulting in various growth, development and health problems (Wenhold et al., 2007). Sweet potato is probably one of the most under-utilized crops in this group (Woolfe, 2003) and is often considered a "small" farmer's crop. Yet it can produce average yields even on poor soils, and with irrigation and fertilization, yields can improve significantly.

Table 6.6: Yield, water use, and WUE for selected yellow or orange vegetables

Product	Yield* t ha^{-1}	Water used mm	WUE* kg ha^{-1} mm^{-1}	Source	Locality
Butternut	16.4	370	44.3	Fanadzo (2009)	Fort Hare, SA
Carrots	67.4-103.6	-	19.4-28.3	Quezada et al. (2011)	Chile
	57.6	390	148	Annandale & Jovanovic (1999a; 1999b)	Roodeplaat, SA
	30.3-64.7	201-493	131-148	Nortje (1988)	South Africa
Sweet potato	10.8-25.8	500	21.6-51.6	Beletse et al. (2011)	Roodeplaat
	13-47	182-1400	33.4-71.1	Laurie et al. (2009)	South Africa
	20.1-34.2	350-850	42.8-57.4	Gomes and Carr (2003)	Mozambique
	40-55	400-500	70-130	Bok et al. (2000)	South Africa
Pumpkin	36-43	162	222-266	Zotarelli et al. (2008)	Florida, USA
	57-66	258-410	160-220	Fandika (2011)	New Zealand
Yams	14.1-21.9	430-710	19.2-23.6	Olanrewaju et al. (2009)	Nigeria
	10-27			Diby et al. (2011)	Ivory Coast

* All yields and WUE values expressed on a ***fresh mass*** basis

Table 6.6 shows WUE values reported in literature for some yellow and orange vegetables. The published WUE values per crop show similar variability as the DGLVs. For example, South African literature gives WUE values for sweet potatoes ranging from 20 to 130 kg ha^{-1} mm^{-1} (Bok et al., 2000; Laurie et al., 2009; Beletse et al., 2011), whilst Gomes and Carr (2003) report a narrower range of 43-57 kg ha^{-1} mm^{-1} for Mozambique. In this group of yellow and orange vegetables, pumpkins (222-266 kg ha^{-1} mm^{-1}), carrots (131-148 kg ha^{-1} mm^{-1}) and sweet potatoes (70-130 kg ha^{-1} mm^{-1}) all show potential to achieve high WUE's under optimal conditions. In general, this group tends to have far higher WUE's than the dark green leafy vegetables. This can be explained by the fact that yields of crops this group (yellow and orange vegetables) is expressed in terms fresh mass, compared to dry matter yields reported for DGLS's.

Water use efficiency of legumes

Legumes are an important source of proteins in the diets of South Africans. In South Africa not enough legumes are produced to meet local consumption and therefore about 58000 tons of dry beans have to be imported annually (Jones, 1999).

Legumes are ideal for inclusion in low input agriculture systems, since they can form a symbiotic relationship with *Rhizobium* bacteria to convert atmospheric nitrogen into ammonia and nitrates, which can be utilized by plants. Legumes are, therefore, often intercropped with cereal crops such as maize to supplement nitrogen in the soil. The problem of low nitrogen levels in infertile soils, which can negatively alter crop yields and WUE (Passioura & Angus, 2010), is therefore overcome.
Typical WUE values for the different legumes are given in Table 6.7. It is clear that these values are substantially lower than those for DGLV's or yellow and orange vegetables. This difference can mainly be ascribed to the fact that legume yields and WUE's are usually expressed on a dry mass basis, while for vegetables they are expressed on a fresh mass basis. However, care should be taken to distinguish between legumes that are consumed fresh (e.g. garden runner beans used as a vegetable; WUE of 38 to 63 kg ha^{-1} mm^{-1}; Table 6.4) and dry beans (cooked as a source of protein; 3 to 6 kg ha^{-1} mm^{-1}; Table 6.7), since for green beans WUE is normally expressed on a fresh yield basis (like that of vegetables), while grain yields and WUE values are expressed on a dry mass basis. It is also important to remember that one expects lower water use efficiencies on a mass basis for protein and oil rich crops due to the energy requirement for the synthesis of amino acids and lipids, as was previously explained.

Table 6.7: Yield, water use and WUE values published for legumes

Product	Yield *	Water use	WUE	Source	Locality
	t ha^{-1}	mm	kg ha^{-1} mm^{-1}		
Groundnuts	2.4-4.8	712-809	3-6	Ehlers et al. (2003)	South Africa
	2-4.5	-	6-8	FAO (2011)	Not specified
	3.5-1.5	655	6-8	Wallender & Renault (2000)	World
	1.3	400	3.3	Jewitt et al. (2009)	South Africa
	-	-	1-4	Molden et al. (2010)	World
Dry beans	1.5-2	300-500	3-6	FAO (2011)	World
	1.5-2	548	3-6	Wallender & Renault (2000)	World
Broad beans	0.91-1.56	495	2.4-2.9	FAO (2011)	South Africa
Soybean	1.5-2.5	803	1.9-3	Wallender & Renault (2000)	World
	1.5-2	450-700	4-7	FAO (2011)	South Africa
	1.6-1.7	451-700	2.4-3.5	FAO (2011)	South Africa
Pigeon peas	0.6-0.8	350-500	1.5-2.0	FAO (2011)	World
Lentils	-	-	3-10	Molden et al. (2010)	World
Cowpea	0.1-0.25	78-258	1.1-2.0	Beletse et al. (2009)	South Africa
	0.50-1.6	480	0.53-1.53	Babalola (1980)	Nigeria
	2.6-3.9	600	4-6	Shiringani & Shimelis (2011)	South Africa

* All yields and WUE values expressed on a ***dry mass*** basis

Most legumes have WUE values in the range of 4-8 kg ha^{-1} mm^{-1}, with the exception of cowpea, which generally showed lower WUE's of around 1-6 kg ha^{-1} mm^{-1} (Table 6.7).

Water use efficiency of staple or cereal crops

Cereal crops (maize and sorghum) are staple foods in most southern African countries, including South Africa. They are also utilized in production of silage for livestock feeding in winter and the grains are also consumed as concentrates by livestock. Maize is mostly used to prepare porridge for lunch and supper in many parts of South Africa, because it is a rich source of carbohydrates, whilst sorghum is utilized to prepare soft porridge for breakfast.

WUE values reported for maize and sorghum range from 4 to 16 kg ha^{-1} mm^{-1} (Table 6.8), with an average value of around 8 kg ha^{-1} mm^{-1}. The wide range of WUE values achieved can most likely be attributed to factors such as crop management, experimental treatment applied, plant nutrient status and soil type, which all affect crop growth and water productivity (Passioura & Angus, 2010).

Table 6.8: Yield, water use, and WUE values published for selected cereal crops

Product	Yield * t ha^{-1}	Water used mm	WUE* kg ha^{-1} mm^{-1}	Source	Locality
Maize	1.58-3.9	400-700	4-7	Igbadan et al. (2006)	Not specified
	2.7-3.3	400-700	6-8	Jewitt et al. (2009)	South Africa
	5.5-6.8	607-644	8.7 11.3	Katerji & Mastrorilli (2009)	Mediterranean
	3-5	558	5.4-9.0	Van Pletzen et al. (1991)	South Africa
	13.9-15.9	897-1006	14.3-15.5	Ehlers et al. (2003)	South Africa
	2.28-3.1	386	6.3-10	Hensley et al. (2000)	South Africa
Sorghum	3.5-5	450- 650	6-10	FAO (2011)	World
	2.2-3.5	300	6-10	Jewitt et al. (2009)	South Africa
	2.0-3.32	386	8.5-9.7	Hensley et al. (2000)	South Africa

* All yields and WUE values expressed on a ***dry mass*** basis

Although sorghum water requirements are on average lower than those of maize, reported WUE values for sorghum (6-10 kg ha^{-1} mm^{-1}) are similar to those for maize (4-16 kg ha^{-1} mm^{-1}), due to lower sorghum grain yields that are usually achieved (Table 6.8).

Due to the fact that less energy is required to produce starch, compared to oils and proteins (Penning de Vries, 1972), the WUE of cereals is generally higher than that of legumes. On the other hand, published WUE's for cereals are usually much lower than those of vegetables due to the fact that the latter is usually expressed on a wet mass basis.

Water use efficiency of fruit crops

Fruit trees can be classified into two types; ‘‘**evergreens and deciduous’’**. Evergreens are active throughout the year whilst deciduous trees shed their leaves in winter which reduces their water use. Deciduous trees have the added advantage of being able to increase water productivity during critical periods of water shortage by shedding their leaves. Avocados, mangos, pawpaw and citrus are evergreens, whereas peaches and apples are deciduous (Sheard et al, 2006). Although some local research has been done on fruit trees (Green & Moreshet, 1979; Beukes et al., 2003; Pavel et al., 2003; Myburgh & Howell, 2006), useful South African literature on fruit tree water use efficiency still remains sparse (Taylor & Gush, 2009). Most of the literature reported here is from Mediterranean countries such as Spain, which have similar conditions to the winter rainfall region of South Africa.

WUE's of fruit crops are also given on a fresh mass basis and range from 9 to 71.4 kg ha^{-1} mm^{-1} (Table 6.9), Maximum WUE values achieved (around 70 kg ha^{-1} mm^{-1}) are, however, substantially lower than those of vegetables (up to 260 kg ha^{-1} mm^{-1}; also on a fresh mass basis). This can be ascribed to the fact that trees have to invest energy into structures such as stems and branches, resulting in less energy to produce fruits.

Table 6.9: Yield, water use, and WUE values published for selected fruit crops

Product	Yield *	Water use	WUE*	Source	Locality
	t ha^{-1}	mm	kg ha^{-1} mm^{-1}		
Mango	18.4	260-590	31-71.4	Duran Zuazo et al. (2011)	Spain
	22-33	428-444	51-74	Pavel et al. (2003)	South Africa
Peach	6.0-16.3	482-705	12.4-23.1	Alegre et al. (1999)	Spain
	30-45	590-780	51-58	Beukes et al. (2003)	South Africa
Apple	26.8	1037	25.8	Renault & Wallender (2000)	USA
	31-43	680-825	45-52	Leib et al. (2006)	USA
Avocado	8-10 (Y)	1000	9	Sheard et al. (2006)	South Africa
	12-15	1000	13.5	Sheard et al. (2006)	South Africa
	15-20 (M)	1000	17.5	Sheard et al. (2006)	South Africa
Orange	25-40	973	25.7-41.1	Wallender & Renault (2000)	World
	25-40	900-1200	27-33.3	FAO (2011)	World
	20-35	900-1200	22-29.2	FAO (2011)	World

* All yields and WUE values expressed on a ***fresh mass*** basis

Table 6.9 shows that WUE's of tree crops vary substantially within a species, for reasons already mentioned (management, locality, environment, etc.). For some species such as oranges and apples variability in WUE is less (range of 20-30 kg ha^{-1} mm^{-1}). Mango appears to have the highest WUE values among the fruit crops.

It is important to note that tree production, and therefore WUE, is influenced by the age and size of a tree. Trees usually take a couple of years to come into full production, and therefore young trees have lower production than mature trees. For example, Table 6.9 indicates that young avocado trees (Y) have a similar water use to mature trees (1000 mm), but their production is only 9 t ha^{-1}, whereas the mature trees produce 20 t ha^{-1}. As a result, their WUEs differ substantially (from 9 kg ha^{-1} mm^{-1} for young trees to 17.5 kg ha^{-1} mm^{-1} for mature trees). Avocado is also rich in oil, so lower WUEs are also to be expected.

Another important factor that results in variable WUE within a species is alternate bearing. Some species, such as avocado, produce higher yields in alternate years. This result from fluctuating reserve levels in the tree, and will obviously have a tremendous effect on the WUE recorded in any year.

Water use efficiency of other selected vegetables

Other vegetables which are of importance in South Africa include tomatoes, onions, cabbage, garlic, potato, and beetroot. Most of these vegetables are used as salads or are cooked and served with meals. Furthermore, potatoes are used to make chips and starch dishes.

The WUE of crops in this group differ vastly within and between species, ranging from as low as 1.5 kg ha^{-1} mm^{-1} for green peppers to 327 kg ha^{-1} mm^{-1} for cabbage (Table 6.10). Cabbage (200 -327 kg ha^{-1} mm^{-1}) and potatoes (136-161 kg ha^{-1} mm^{-1}) are the most efficient in utilising water, compared to other vegetable crops in this group (expressed on fresh yield basis). It must once again be noted that for most of these commercial crops farmers with good management and knowledge levels are able to achieve substantially higher yields than what is mentioned here (close to potential yields).

Table 6.10: Yield, water use, and WUE for other vegetable crops

	Yield *	Water used	WUE*		
Product	t ha^{-1}	mm/	kg ha^{-1} mm^{-1}	Source	Locality
Green pepper	10-25	600-900	1.5-3	FAO (2011)	World
	15-20	500	3-4	Molden et al. (2010)	World
Tomato	45-65	622	4-7	Wallender & Renault (2000)	World
	45-65	400-600	10-12	FAO (2011)	World
	45-65	401-600	10.8-11.2	FAO (2011)	World
Onion	35-45	711	8-10	Wallender & Renault (2000)	World
	35-45	350-550	8-0	FAO (2011)	World
	35-45	351-550	9-0	FAO (2011)	World
Garlic			20.1-27.8	Tayel et al. (2010)	Egypt
Cabbage	25-85	380-500	120-200	FAO (2011)	World
	42.9	350	123	Annandale & Jovanovic, (1999a; 199b)	South Africa
	75-115	322-406	285-327	Nortje (1988)	South Africa
Potato	20-33	282-300	70-111	Ehlers et al. (2003)	South Africa
	22-47	259-579	39-161	Steyn et al. (2007; 2008)	South Africa
	15-25	500-700	40-70	FAO (2011)	Mediterranean
	15-20	501-700	29-32	FAO (2011)	Mediterranean
	46-65	340-820	80-136	Steyn et al. (1998)	South Africa
	-	-	30-70	Molden et al. (2010)	World
Beetroot	8.7-12	500	17.4-24	Brown et al. (1987)	World

* All yields and WUE values expressed on a ***fresh mass*** basis

6.2.3. Water use in animal production

Introduction

Livestock farming is often the most important livelihood for small holder farmers in Africa and is a major consumer of water (Descheemaeker et al., 2010). The first essential requirement for living organisms is water. Water constitutes 80% of animal body mass, and deprivation will lead to reduced feed intake, lower production and reproduction, poor health and eventually death.

The projected increase in human population will lead to increased urbanization and changes in diets of people, which will further increase the demand for animal products. It is estimated that demand for animal products will increase by 3.2% per annum (Renault & Wallender, 2000; Descheemaeker et al., 2010; Mekonnen et al., 2010b). The major consumer of water in livestock production is the water needed to grow feed. Water used to produce fodder is 50 times greater than that needed by livestock for drinking purposes (Peden et al., 2007). Many factors affect the drinking water requirements of livestock (type and size of animal or bird, physiological state, diet type, temperature, walking distance, production system used, etc.), but this will not be discussed in detail here considering the negligible contribution this makes to the total water footprint.

Principles of animal product water productivity

Here we discuss some of the underlying principles affecting water requirements of livestock derived food products. Specifically the following unprocessed food products will receive attention:

- Beef
- Mutton
- Goat meat
- Pork
- Chicken
- Eggs
- Milk

The brief section that follows covers a few principles of animal nutrition and was explained to the authors by an animal nutritionist from the University of Pretoria, Prof Willem van Niekerk. Firstly it is important that we distinguish between *ruminants* and *monogastric* animals. Ruminants like cattle and sheep, have four developed stomachs that enable them to utilize roughages efficiently, this compared to monogastric animals, which mostly rely on more concentrated diets. This is an important distinction for our analysis, as most roughage will be produced with green water, but concentrates may be produced with either green or blue water. It is interesting to note that nearly all of our national breeding cows and sheep are kept under extensive conditions, but more than 75% of all cattle slaughtered go through the feedlot system.

We expect cattle to be less efficient than sheep or goats at converting roughage to meat, as smaller stock have lower basal metabolic rates than the larger framed animal. This means that the small stock have more energy available for productive purposes than cattle per unit feed intake. Another reason for greater efficiency of sheep is that they are able to graze more selectively than cattle, and will therefore access more nutrient rich food, which will more efficiently be converted to meat.

Pigs and poultry are highly efficient feed converters. This is partly due to the composition of the feed they receive as monogastrics (highly digestible concentrates) compared to poorly digestible roughages fed to ruminants. However, there is a fundamental difference in the two digestive systems – with monogastrics, the end products of digestion are directly absorbed and used in the metabolism of products, whereas in the ruminant digestive tract, end products need to be further digested or converted before they can be used for metabolism- a far less efficient utilization mechanism. Slaughter percentage can be equated with our discussion on harvest index, and typical values for ruminants are around 50% for cattle and 70% for chicken. These are additional reasons why poultry are more efficient than cattle at converting feed (that needs water to produce) into an edible product.

Eggs and milk contain predominantly water (milk is 89% water) and much less protein than meat. One would therefore expect a smaller water footprint for these products. Table 6.11 presents water use efficiency figures for these livestock derived food products.

Table 6.11: Water footprints of various animal products (Mekonnen et al., 2010a,b; Wallender & Renault, 2000)

Animal product	Water use per ton ($m^3\ ton^{-1}$) (Mekonnen et al., 2010b) Global	Water use per ton ($m^3\ ton^{-1}$) (Wallender & Renault, 2000) USA	Water use per ton ($m^3\ ton^{-1}$) (Mekonnen et al., 2010a) South Africa
Beef	15400	13500	5200
Sheep	10400	-	4900
Goat meat	5500	-	6000
Pork	6000	4600	5000
Chicken	3300	4100	3800
Eggs	-	2700	3500
Milk	-	790	1020

The values from different sources show similar trends, and generally tend to support the principles highlighted above. However, it would be useful to undertake more accurate water foot-printing studies under local conditions, as these figures are derived from large scale global studies that understandably need to rely on some fairly coarse assumptions.

Water requirements to produce feed for animals

According to Beckett and Oltjen (1993), water for livestock is not only required for drinking purposes, but also for producing feed and processing of livestock into meat. In the USA beef cattle consume 760 billion litres per year (drinking water), irrigated feedstuffs use 12991 billion litres per annum, whilst carcass processing utilizes 79 billion litres per annum (Beckett & Oltjen, 1993). From these numbers it is clear that water is mostly consumed for feed production and not for drinking by the livestock itself (Note that 13.8 million head of beef cattle were used in this study). Table 6.12 gives water use data for selected feed.

Table 6.12: Water use of different feedstuffs used for livestock feeding in the USA (Beckett & Oltjen, 1993)

Type of feedstuff	Water use (m^3 ton^{-1})
Alfalfa (lucerne)	257
Wheat	119
Sorghum	118
Barley	217
Corn (maize)	77
Silage	27

The values in this table look too low, but the general ranking of water use efficiencies seems to make sense. From our previous discussions, we would expect the high protein leguminous lucerne crop to have a lower WUE than the high energy C4 maize crop. Silage appears to be very efficient, but this product is fed at a very high water content, and the table value is likely reported on a wet mass basis.

Water productivity of livestock

Livestock water productivity (LWP) is the ratio of the net beneficial livestock related products and services to the water depleted (Peden et al., 2009; Descheemaeker et al., 2010):

$$\textbf{Water productivity of livestock} = \frac{\sum \textbf{[Livestock outputs and services]}}{\textbf{Water depleted}}$$

A framework for assessing livestock water productivity explains water use by livestock and products produced in detail (Figure 6.6). This shows water inflows to the system (surface water, groundwater and precipitation), and water outflows are water used for feed production, drinking and processing the animal product. Animal outputs and services are milk, meat, hides, draught power and wealth. Water is depleted by evaporation and transpiration. Strategies available to improve LWP are improvement in water management, ration selection, and grazing management (Descheemaeker et al., 2010).

In a global study, Mekonnen et al. (2010b) conducted research on estimating water footprints of livestock products (beef, sheep, goat, pork, poultry, milk, and eggs) by considering water used for producing feed and servicing the animal product. Table 6.13 presents water footprints and water productivities for various livestock products in South Africa. It is evident that water use by livestock depends on the production system. It is important to note here that these authors have a somewhat different definition of grey water – here it is defined as the volume of fresh water required to assimilate the load of pollutants based on existing ambient water quality standards.

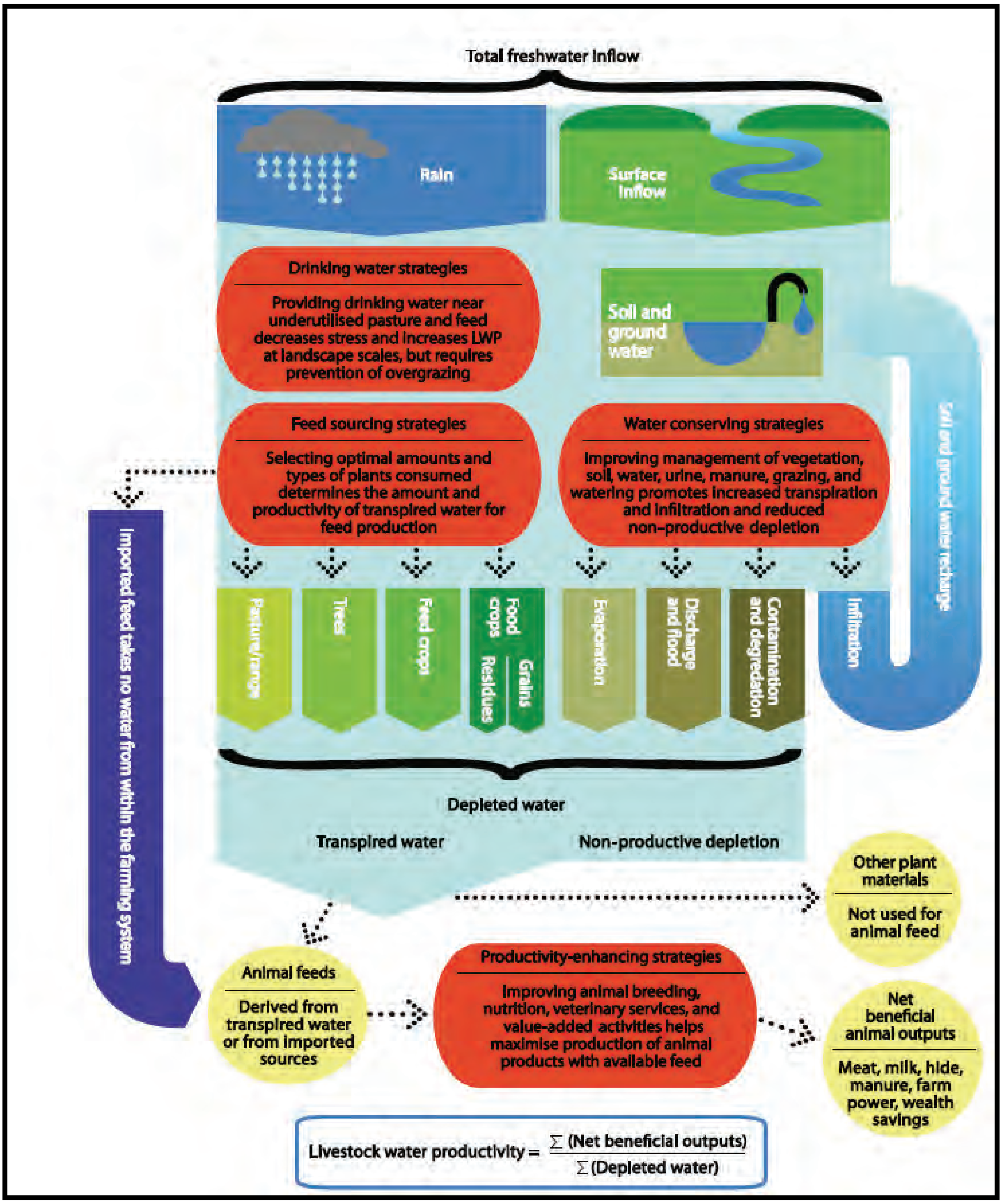

Figure 6.6: Framework for assessing water productivity for livestock. Water inflows into the system are precipitation, surface water, and groundwater. Water is used for biomass production, servicing and processing. Animal outputs are meat, milk, hides, manure, and wealth (Peden et al., 2009).

Table 6.13: Water footprint and water productivity for different livestock in South Africa as from 1996-2005 (Mekonnen et al., 2010a)

Product description	Production system	Water footprint (m^3 ton^{-1}) *				Water productivity (kg m^{-3}) *			
		Grazing	Mixed	Industrial	Weighted average	Grazing	Mixed	Industrial	Weighted average
Pork	Green	4715	5345	4246	4976	0.21	0.19	0.24	0.20
	Blue	498	387	310	419	2.01	2.58	3.23	2.39
	Grey	297	330	262	309	3.36	3.03	3.82	3.23
Sheep	Green	6033	2687	1220	4868	0.17	0.37	0.82	0.21
	Blue	180	201	251	189	5.57	4.98	3.98	5.28
	Grey	7	25	33	13	141.29	40.68	30.41	76.69
Goats	Green	8264	4063	1740	5992	0.12	0.25	0.57	0.17
	Blue	142	148	190	152	7.03	6.75	5.28	6.58
	Grey	1	2	5	2	1667	565	195	615
Poultry	Green	5429	3224	1999	3809	0.18	0.31	0.50	0.26
	Blue	188	114	70	133	5.32	8.75	14.37	7.50
	Grey	361	214	133	253	2.77	4.67	7.53	3.95
Milk	Green	1029	640	-	1019	0.97	1.56	-	0.98
	Blue	40	37	-	41	24.87	27.18	-	24.41
	Grey	40	39	-	40	25.12	25.39	-	25.12
Eggs	Green	6071	3589	2578	3527	0.16	0.28	0.39	0.28
	Blue	220	136	102	134	4.54	7.34	9.81	7.46
	Grey	410	242	174	238	2.44	4.13	5.75	4.20
Beef	Green	8260	7545	4497	5173	0.12	0.13	0.22	0.19
	Blue	385	411	518	446	2.60	2.44	1.93	2.24
	Grey	452	489	615	531	2.21	2.04	1.63	1.88

* Water footprint values were converted to water productivity.

It would be useful to do a thorough analysis of the water footprint of animal derived food products under South African conditions, especially one that attempts to separate out the contribution of green and blue water to different production systems.

6.3 NUTRITIONAL WATER PRODUCTIVITY

6.3.1 Introduction

The water productivity (WP) slogan of the Food and Agriculture Organization (FAO), is ‘‘more crop per drop’’, meaning the production of more food per millimetre of water used. Agriculture is always singled out as the largest consumer of water, competing with industrial and domestic users. In South Africa the agricultural sector consumes approximately 50% of the available water resources (Earth Trends, 2003). Future challenges would be to balance population growth, nutritional requirements for diets, and available water resources (Renault & Wallender, 2000; van Dam & Malik, 2003). The definition of WP depends on the field of expertise. An agronomist would be interested in more yield per unit water

consumed (actual evapo-transpiration – ETa) so WP = Yield / ETa, whilst a nutritionist's objective may be, for example, more calories per unit water consumed (van Dam & Malik, 2003).
One of the strategies in trying to improve water productivity of crops and animal food products is through the practise of deficit irrigation. Deficit irrigation is an optimisation strategy whereby irrigation is applied during drought sensitive growth stages of a crop. This is aimed at obtaining maximum WP, rather than maximum yields (Geerts & Raes, 2009). In the process of altering yields to increase WP, we are unsure of what happens to the nutritional value of food products. Do nutrient contents decrease or increase? This is an important research area for scientists to focus on, so called ***nutritional water productivity*** (NWP)*,* in an attempt to alleviate the problem of malnutrition, especially in developing countries such as South Africa (Renault & Wallender, 2000).

Malnutrition in South Africa

Wenhold and Faber (2007) identified two types of malnutrition in South Africa:

- **Undernutrition**: protein-energy malnutrition and micronutrient deficiencies.
- **Overnutrition**: excessive intake of energy and macronutrients

The most important micronutrient deficiencies globally are iron, vitamin A, iodine and zinc. The overweight condition is predominant among South African women. Approximately 52 % of women are overweight or obese at a national level (Wenhold & Faber, 2007). Furthermore, children 1-9 years of age are experiencing stunted growth and are underweight due to malnutrition. Micronutrients which are deficient in the South African population are especially vitamin A, iron and iodine. The World Health Organisation (WHO-1995) notes that approximately 80% of dietary intake of vitamin A comes from plant foods (vegetables and fruits). To supplement micronutrients in South Africa, food fortification is an option. Recently, the Agricultural Research Council conducted a study considering the improvement of the vitamin A content of vegetables such as spinach. Spinach has been chosen because it grows easily, and many rural households in the country have knowledge on how to grow this vegetable crop (Nyathi et al, 2011).

Since agriculture is the largest consumer of water (70% globally) it is faced with the challenge of reducing its water consumption. However, practising strategies such as deficit irrigation or supplemental irrigation should not compromise the nutritional values of crop and animal food products, because the resource poor population will be the most affected.

It is useful to set benchmarks for nutritionally important crop and animal food products. We will use the definition of nutritional water productivity (NWP) of Wallender & Renault (2000):

NWP = Ya/ ETa * NP

Where Ya is actual harvested yield (kg ha^{-1}), ETa actual evapo-transpiration (m^3 ha^{-1}), and NP the nutritional content per kg of product (nutrition unit kg^{-1}). Units of NWP are therefore nutrition unit per m^3 of water (Renault & Wallender, 2000).

Aims and objectives

The major aims and objectives of this part of the report are to calculate initial estimate benchmarks of nutritional water productivity for key nutrients of selected crops (cereals, legumes, fruit, dark green leafy vegetables, and yellow / orange vegetables) and animal food products, and to put these in perspective with a brief discussion of the results, and to highlight possible future research needs. The key nutrients considered are energy, protein, fat, carbohydrate, calcium, iron, zinc, copper, manganese, β-carotene, vitamin A, thiamin, riboflavin, niacin, vitamin $B_{6,}$ folate, vitamin $B_{12,}$ vitamin C.

6.3.2 International benchmarks for energy and macronutrient water productivity

Published values of macronutrient water productivities are presented in this section. Table 6.14 depicts the macronutrient content (calories, protein, and fat) of selected products in Canada, Ghana and the USA:

Table 6.14: Nutrient content and nutritional water productivity (NWP) (macronutrients)

		Nutrient			NWP			Location	Source*
	Product	Energy	Protein	Fat	Energy	Protein	Fat		
Product type		kcal kg^{-1}	g kg^{-1}	g kg^{-1}	kcal m^{-3}	g m^{-3}	g m^{-3}		
		1376	135	89	102	10	7	USA	1
	Beef	1550	206	-	68	9	-	Canada	2
	Eggs	1402	110	98	519	41	36	USA	1
		521	32	30	659	40	38	USA	1
	Milk	640	33	-	773	40	-	Canada	2
		1879	97	162	408	21	35	USA	1
	Pork	1680	200	-	339	40	-	Canada	2
		1354	135	86	330	33	21	USA	1
Animal	Poultry	1140	205	-	278	50	-	Canada	2
	Cabbage	250	14	-	3289	89	-	Canada	2
	Carrots	25	10	-	2174	87	-	Canada	2
		331	12	0	2259	85	0	USA	1
	Onions	331	12	0	880	31	0	Ghana	3
	Pepper	200	12	-	38	2	-	Canada	2
		591	16	1	5626	150	9	USA	1
	Potatoes	700	20	-	5785	165	-	Canada	2
	Tomatoes	184	8	1	1416	65	11	USA	1
Vegetables	Watermelon	370	6	-	2256	37	-	Canada	2
	Green beans	330	24	-	935	68	-	Canada	2
	Groundnut	6067	283	526	2382	111	206	USA	1
	Peas	2720	229	-	8889	748	-	Canada	2
		3470	-	-	2828	304	-	Canada	2
		4160	-	200	956.8	83.95	46	Ghana	3
		170	10	-	3542	208	-	Canada	2
Legumes	Soybean	184	-	1	248	10.8	1.35	Ghana	3
		441	2	2	1140	6	6	USA	1
Fruit	Apple	540	3	-	1395	8	-	Canada	2

	Product	Nutrient			NWP			Location	Source*
		Energy	Protein	Fat	Energy	Protein	Fat		
	Orange	250	5	0	663	13	0	USA	1
Grain	Maize	2738	55	12	3856	77	17	USA	1
		3270	85	-	8583	223	-	Canada	2
		2738	55	12	547.6	11	2	Ghana	3

* 1. Renault & Wallender (2000) 2. Brooks & Grauenhorst (2008) 3. Mdemu et al (2009)

Energy

In the table, energy concentration is presented in kcal kg^{-1} and nutritional water productivity is in kcal m^{-3}. It is not surprising that soybean and groundnuts (3470-6067 kcal kg^{-1}) possess a higher concentration of energy than a cereal crop like maize (2738- 3270 kcal kg^{-1}). Generally fats provide twice the energy of carbohydrates. However, when we consider NWP, it is striking that groundnuts and soybean have much lower efficiencies than cereal crops. This may have to do with the energy invested in biological nitrogen fixation – as leguminous crops basically trade water for nitrogen. Animal products generally use significantly more water to produce a unit of energy, as can be seen from the nutritional water productivity figures (Table 6.14). Although livestock production may not be a particularly water efficient source of energy, it is important to take the "colour" of water into account when considering the wisdom of producing and consuming these products. Often livestock can be produced in areas that are too arid, or soils too marginal for irrigated crop production, and the utilisation of green water through grazing animals is the only way to convert rain water into a usable food product.

Protein and fat

Vegetables and fruits are extremely low in protein and fat, whilst the leguminous crops (soybeans and groundnuts) are rich in these nutrients. The grain crops have intermediate values. Foods from animal origin are well known protein and fat sources, but the nutritional water productivity for these nutrients are well below those for the leguminous crops.

6.3.3 South African nutritional water productivity data

Published literature for NWP of crops and animal food products for South Africa is limited. This suggests that there is much scope for future research on this important topic. To determine a rough estimate of NWP for South African conditions, we used the equation suggested by Renault and Wallender (2000). Nutritional contents of cereal crops and animal food products were adopted from Chapter 5, and water productivity values were taken from this chapter. Both sets of values have their weaknesses (inaccuracies), but this exercise should serve as a useful starting point and initial attempt at benchmarking nutritional water productivities for South African conditions. Perhaps the greatest weakness of this approach is that the calculations are not done with data from the same trials – so we are assuming that yields and water use data can be linked to published average nutritional quality data. There is also great uncertainty regarding the moisture content of the harvested product, and this has a very important effect on the nutrition quality. Specifically water content adjustments were made to nutritional data for Amaranth and Maize – the macronutrient contents were adjusted for amaranth from 89% water content to oven dry to match the trial of Beletse and colleagues (2009), and the maize nutritional data was assumed to be for green mealies (76% water content) and was adjusted arbitrarily to 10% for both macro- and micronutrient analyses.

The macronutrients for specific food products (energy, protein, fat and carbohydrates) are presented in Table 6.15, and a comprehensive list of micro-nutrients are presented in Tables 6.17 and 6.18. The sources are referenced in Table 6.15 and refer to values presented earlier in this chapter. The same sources are used in Tables 6.17 and 6.18, but are not shown due to space constraints.
Specific observations from these tables are discussed, the values are summarised into broad food groupings and future research opportunities briefly explored.

Table 6.15: Nutrient content, water productivity and nutritional water productivity (macronutrients) in South Africa

Food				Nutrient content / kg of product				NWP (nutritional unit m^{-3})			
	WP	WP	Moisture	Energy	Protein	Fat	Carbs*	Energy	Protein	Fat	Carbs*
	kg m^{-3}	Reference	%	MJ kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	MJ m^{-3}	g m^{-3}	g m^{-3}	g m^{-3}
ANIMAL FOODS											
Mutton	0.10	Mekonnen et al. (2010b)	61	11	169	216	-	1.09	17	22	-
Goat	0.17	Mekonnen et al. (2010b)	76	4.4	206	23	-	0.74	35	4	-
Beef	0.06	Mekonnen et al. (2010a)	65	8.5	192	142	-	0.51	12	9	-
Pork	0.20	Mekonnen et al. (2010a)	50	15.4	139	351	-	3.07	28	70	-
Chicken	0.26	Mekonnen et al. (2010a)	74	4.9	230	27	-	1.28	60	7	-
Eggs	0.29	Mekonnen et al. (2010a)	75	6.2	126	103	12	1.79	37	30	3
Milk, whole	0.98	Mekonnen et al. (2010a)	88	2.6	32	34	48	2.57	31	33	47
VEGETABLES											
Butternut	2.2	Fanadzo (2009)	85	2.4	16	1.0	108	5.3	35	2	238
Carrot	14	Nortje (1998)	89	1.7	9.0	0.0	64	24	126	0	896
Leaves, pumpkin	19	Fandika (2011)	93	1.1	32	4.0	4	21	608	76	76
Leaves, sweet potato	5.2	Laurie et al. (2009)	88	1.9	40	3.0	44	9.8	208	16	229
Sweet potato	5.2	Laurie et al. (2009)	73	4.5	17	1.0	213	23	88	5	1108
Pumpkin	19	Fandika (2011)	92	1.3	8.0	1.0	47	24	152	19	893
Hubbard squash	-	-	91	1.5	7.0	1.0	66	-	-	-	-
Kale	-	-	85	2.5	33	7.0	80	-	-	-	-
Leaves, amaranth	2.2	Beletse et al. (2009)	0	14.5	263	18	145	32	578	40	319
Leaves, black jack	-	-	85	2.2	34	4.0	24	-	-	-	-
Leaves, cat's whiskers	0.48	Beletse et al. (2012)	85	2.2	46	9.0	17	1.1	22	4.3	8.2
Leaves, Chinese cabbage*	1.9	Beletse et al. (2012)	95	0.9	9	1.0	22	1.7	17	1.9	42
Leaves, cowpea	0.53	Beletse et al. (2012)	86	1.8	45	4.0	15	0.95	24	2.1	8

Nutrient content, water productivity, and nutritional water productivity (macronutrients) in South Africa (continued)

				Nutrient content / kg of product				NWP (nutritional unit m^{-3})			
	WP	WP	Moisture	Energy	Protein	Fat	Carbs*	Energy	Protein	Fat	Carbs**
Food	kg m^{-3}	Reference	%	MJ kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	MJ m^{-3}	g m^{-3}	g m^{-3}	g m^{-3}
VEGETABLES											
Leaves, lambquarters	-	-	85	1.9	44	3.0	19	-	-	-	-
Leaves, nettle	-	-	80	2.7	54	7.0	24	-	-	-	-
Leaves, nightshade	2.9	Beletse et al. (2012)	83	2.4	53	4.0	22	7	154	12	64
Leaves, sow thistle	-	-	90	1.3	22	5.0	12	-	-	-	-
Spinach (small leaved)	3.2	Walker (2000)	92	1.2	29	4.0	8	3.8	93	16	26
Swiss chard	3.2	Walker (2000)	90	1.3	27	2.0	16	4.1	86	6.4	51
Cabbage	12.3	Annandale & Jovanovic (1999a)	92	1.4	15	1.0	43	17	185	12	529
Green pepper	0.35	Molden et al. (2010)	95	1.0	9.0	1.0	31	0.36	3	0.35	11
Leaves, beetroot	9.6	Hygrotech	92	1.0	18	1.0	3	9.8	173	10	29
FRUIT											
Apricot	-	-	87	1.6	8	1.0	65	-	-	-	-
Loquat	-	-	87	2.2	4	2.0	104	-	-	-	-
Mango	5.1	Duran Zuazo et al. (2011)	82	3.0	6	2.0	153	15	31	10	780
Melon, orange	5.3	Hygrotech	89	1.7	8	1.0	82	9.2	42	5	435
Paw-paw	-	-	89	1.9	4	1.0	86	-	-	-	-
Peach, yellow	5	Beukes et al. (2003)	86	2.4	8	1.0	109	12	40	5	545

Carbs** Carbohydrates

Nutrient content, water productivity, and nutritional water productivity (macronutrients) in South Africa (continued)

				Nutrient content / kg of product)				NWP (nutritional unit m^{-3})			
	WP	WP	Moisture	Energy	Protein	Fat	Carbohydrates	Energy	Protein	Fat	Carbohydrates
Food	kg m^{-3}	Reference	%	MJ kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	MJ m^{-3}	g m^{-3}	g m^{-3}	g m^{-3}
LEGUMES											
Peanuts	0.43	Ehlers et al. (2003)	6.5	25	258	492	76	11	111	212	33
Beans, dried	0.45	FAO (2011)	12	15	223	13	355	6.6	100	6	160
Beans, broad	0.27	FAO (2011)	12	15	169	13	462	3.9	4.6	4	125
Chick peas	0.18	FAO (2011)	11	15	261	15	354	2.7	47	3	64
Lentils	0.65	Molden et al. (2010)	12	16	193	60	460	10	125	39	299
Peas	0.18	FAO (2011)	9.9	15	255	7	407	2.7	46	1	73
Soybeans	0.72	Ehlers et al. (2003)	11	15	246	12	349	11	177	9	251
GRAINS											
Maize	1.1	Katerji & Mastorilli (2009)	10	15.7	120	45	611	17.3	132	50	672

Chinese Cabbage* (*Brassica rapa L subsp. Chinensis*)

Macronutrient water productivity

For all food products there is a wide range in nutritional water productivities, probably due to the errors committed with making calculations with two independent data sets – this is not ideal, and it is clear that we need to encourage these calculations to be made with single reliable data sets. Data from Table 6.15 is summarised into food groups in Table 6.16.

Energy
Most food groups had products that seemed to be quite energy efficient in terms of water consumed per MJ produced, with the exception being the animal derived products. Here it is important to remind ourselves about the use of natural veldt, which can only be utilised to produce animal products (use of so called green water), so one needs to be cautious not to outright discourage the production of these food sources solely on their low water use efficiencies. Crops with high efficiencies in this study were maize (17.3 MJ m^{-3}), mango (15 MJ m^{-3}), cabbage (17 MJ m^{-3}), for the DGLV amaranth (32 MJ m^{-3}), yellow/orange vegetables – carrot, sweet potato and pumpkin (24 MJ m^{-3}), and leguminous crops – soybeans and groundnuts (11 MJ m^{-3}).

Protein and Fats
Despite animal products being relatively rich protein and fat sources, their large water footprints make them relatively inefficient sources of these nutrients (chicken and pork most efficient at around 60-70 g m^{-3}). It is interesting to note that some of the DGLV appear to be exceptionally efficient protein synthesisers (pumpkin leaves 608 g m^{-3} and amaranth at 578 g m^{-3}). The leguminous crops are quite efficient protein and lipid synthesisers, with soybeans exhibiting a protein water productivity of 177 g m^{-3}, and groundnuts a protein and fat water productivity of 111 and 212 g m^{-3} respectively. Maize was also very efficient (132 g protein m^{-3} and 50 g fat m^{-3}), and some of the orange/yellow vegetables and other vegetables did quite well too (pumpkin 152 and cabbage 185 g protein m^{-3}). Fruit are poor sources of protein, and as expected their nutrient productivities were very low.

Table 6.16: Summary comparing macronutrient NWP for crops and animal products

Product type / Nutrients	Energy (MJ m^{-3})	Protein (g m^{-3})	Fats (g m^{-3})
Animal products	0.5-3.1	12-60	4-70
DGLV*	1.1-32	17-608	1.9-76
Yellow or orange vegetables	5.3-24	35-152	2-19
Other vegetables	0.36-17	3-185	0.35-12
Fruit	9.2-15	31-42	5-10
Legumes	2.7-11	4.6-177	1-212
Grains	17.3	132	50

* Dark green leafy vegetables

Table 6.17: Nutrient content (mg kg^{-1}), water productivity (kg m^{-3}) and nutritional water productivity (mg m^{-3}) for minerals in South Africa

Food		Nutrient content mg/kg of product						NWP					
	WP	Ca	Fe	Mg	Zn	Cu	Mn	Ca	Fe	Mg	Zn	Cu	Mn
ANIMAL FOODS													
Mutton	0.64	120	16	220	33.3	1	0.19	76.80	10.24	140.80	21.31	0.64	0.12
Goat	0.64	130	28	0	40	2.6	0.38	83.20	17.92	0.00	25.60	1.66	0.24
Beef	0.38	130	7	190	34.2	3.2	0.17	49.40	2.66	72.20	13.00	1.22	0.06
Pork	0.19	190	7	130	15.9	0.6	0.11	36.10	1.33	24.70	3.02	0.11	0.02
Chicken	0.34	140	11	280	7.4	0.6	0.9	47.60	3.74	95.20	2.52	0.20	0.31
Eggs	0.54	390	18	90	11.5	1.2	0.6	210.60	9.72	48.60	6.21	0.65	0.32
Milk, whole	2.78	1200	1	120	3.8	0.1	0.04	3336.00	2.78	333.60	10.56	0.28	0.11
VEGETABLES													
Butternut	2.2	130	4	200	3.1	0.9	1	286.00	8.80	440.00	6.82	1.98	2.20
Carrot	14	310	3	130	1.5	0.2	1.5	4340.00	42.00	1820.00	21.00	2.80	21.00
Pumpkin leaves	19	240	6	100	3.5	0.2	1.1	4560.00	114	1900.00	66.50	3.80	20.90
OFSP*	5.2	280	5	200	2.9	2.1	5.6	1456.00	29	1040.00	15.08	10.92	29.12
Pumpkin	19	180	4	120	2.4	0.9	1.1	3420.00	76	2280.00	45.60	17.10	20.90
Sweet potato L.*	5.2	370	10	610	2.9	0.4	2.56	1924.00	52	3172.00	15.08	2.08	13.31
Amaranth	2.2	2600	48	1280	15.1	2	32.4	5720.00	106	2816.00	33.22	4.40	71.28
Beetroot L.*	9.6	1190	33	720	3.8	1.9	3.91	11424.00	316	6912.00	36.48	18.24	37.54
Chinese cabbage*	1.9	400	4	70	1.4	-	1.6	760	7.6	133	2.7	0	3.0
Leaves, cowpea	0.53	1880	27	600	4	2.7	7.07	996	14.3	318	2.1	1.4	3.8

OFSP* Orange fleshed sweet potato, Sweet potato L.* Sweet potato leaves, Beetroot L.* Beetroot leaves, Chinese cabbage* (*Brassica rapa L subsp. Chinensis*)

Nutrient content (mg kg^{-1}), water productivity (kg m^{-3}) and nutritional water productivity (mg m^{-3}) for minerals in South Africa (continued)

Food	Nutrient content mg/kg of product							NWP					
	WP	Ca	Fe	Mg	Zn	Cu	Mn	Ca	Fe	Mg	Zn	Cu	Mn
VEGETABLES													
Nightshade	2.9	2780	85	840	11.6	3.6	18.6	8062	247	2436	33.6	10.4	54.1
Spinach	3.2	1930	71	510	9	2.5	10.8	6176.0	227.2	1632.0	28.8	8.0	34.4
Swiss chard	3.2	990	27	790	5.3	1.3	9.0	3168.0	86.4	2528.0	17.0	4.2	28.7
Cabbage	12.3	310	3	130	1.5	0.2	1.5	3813.0	36.9	1599.0	18.5	2.5	18.5
Green pepper	0.35	70	9	100	230	1.7	1.2	24.5	3.2	35.0	80.5	0.6	0.4
FRUIT													
Mango	5.1	90	2	100	0.7	0.7	1.4	459.0	10.2	510.0	3.6	3.6	7.1
Melon	5.3	110	4	130	1	1	0.7	583.0	21.2	689.0	5.3	5.3	3.7
Peach, yellow	5	60	3	70	0.9	0.7	0.5	300.0	15.0	350.0	4.5	3.5	2.5
LEGUMES													
Peanuts	0.43	920	46	1680	32.7	11.4	19.34	395.6	19.8	722.4	14.1	4.9	8.3
Beans, dried	0.45	1550	64	1730	25.4	8.8	13.1	697.5	28.8	778.5	11.4	4.0	5.9
Beans, broad	0.55	1030	67	1920	31.4	8.2	16.3	468.0	32.0	902	14	4.8	7.2
Chick peas, dried	0.18	1050	62	1150	34.3	8.5	22	185.4	12.1	345.6	5.7	1.5	2.9
Lentils	0.65	800	69	810	-	-	-	682.5	40.3	747.5	22.3	5.5	14.3
Peas, split	0.18	550	44	1150	30.1	8.7	13.91	144.0	12.4	145.8	-	-	-
Soybeans, dried	0.72	2770	157	2800	48.9	16.6	25.20	396.0	31.7	828.0	21.7	6.3	10.0
GRAINS													
Maize	1.1	20	5	370	4.5	0.5	1.6	83	21	1526	18	2	6.6

Table 6.18: Nutrient content (mg kg^{-1}), water productivity (kg m^{-3}) and nutritional water productivity (mg m^{-3}) for vitamins in South Africa

Food		Nutrient content in mg/ kg of product									NWP								
	WP	β-carot.	Vit A	Thiamin	Ribo flavin	Niacin	Vit B_6	Folate	Vit B_{12}	Vit C	β-carot.	Vit A	Thiamin	Ribo flavin	Niacin	Vit B_6	Folate	Vit B_{12}	Vit C
ANIMAL FOOD																			
Mutton	0.64	0	0	1.2	2.2	61	1.3	0.18	0.024	0	0	0	0.77	1.4	39	0.83	0.12	0.02	0
Goat	0.64	0	0	1.1	4.9	38	0	0.05	0.011	0	0	0	0.70	3.1	24	0	0.03	0.01	0
Beef	0.38	0	0	1.3	0.8	54	2.12	0.1	0.01	0	0	0	0.49	0.30	21	0.81	0.04	0	0
Pork	0.19	0	0.03	6	2.1	38	2.84	0.04	0.006		0	0.01	1.1	0.40	7	0.54	0.01	0	0
Chicken	0.34	0	0.08	1.3	0.8	57	6.1	0.01	0.002	10	0	0.03	0.44	0.27	19	2.1	0	0	3
Eggs	0.54	0	0.66	1.3	4	1	0.42	0.46	0.019	0	0	0.36	0.70	2.2	0.54	0.23	0.25	0.01	0
Milk, whole	2.78	0	0.47	0.2	1.6	1	0.35	0.05	0.004	3.1	0	1.31	0.56	4.4	2.8	0.97	0.14	0.01	9
VEGETABLES																			
Butternut	2.2	5.3	1.28	0.7	0.2	16	1.1	0.23	0	120	12	2.8	1.5	0.44	35	2.4	0.51	0	264
Carrot	14	0.4	0.07	0.4	0.2	3	0.8	0.16	0	300	5.6	0.98	5.6	2.8	42	11.2	2.2	0	4200
Pumpkin L.*	19	159	33	0.3	1.2	6	0.6	0.1	0	40	221	37	5.7	23	114	11.4	1.9	0	760
OFSP*	5.2	130	22	0.7	1.3	6	2.41	0.23	0	250	681	113	3.6	6.8	31	12.5	1.20	0	1300
Pumpkin	19	9.2	1.6	0.2	0.2	6	1	0.04	0	80	175	30	3.8	3.8	114	19	0.76	0	1520
Sweet potato	5.2	6.2	1.1	1.6	3.5	11	1.9	0.8	0	110	32	5.4	8.3	18.2	57	9.9	4.2	0	572
Amaranth	2.2	18	3.3	0.1	1	10	1.8	0.64	0	460	40	7.2	0.22	2.2	22	4.0	1.4	0	1012
Beetroot L.*	9.6	37	6.1	1	2.2	4	1.06	0.15	0	300	351	59	9.6	21	38	10.2	1.4	0	2880
C. cabbage*	1.9	0.5	0.09	0.3	0.2	6	0.6	0.22	0	680	0.95	0.17	0.57	0.38	11.4	1.14	0.42	0	1292
Cowpea L.*	0.53	5.9	0.99	4.9	2.4	16	2.46	1.41	0	500	3.14	0.52	2.6	1.3	8.5	1.3	0.75	0	265

Nutrient content (mg kg^{-1}), water productivity (kg m^{-3}) and nutritional water productivity (mg m^{-3}) for vitamins in South Africa (continued)

Food	Nutrient content mg/ kg of product										NWP								
	WP	β-carot.	Vit A	Thiamin	Ribo flavin	Niacin	Vit B_6	Folate	Vit B_{12}	Vit C	β-carot.	Vit A	Thiamin	Ribo flavin	Niacin	Vit B_6	Folate	Vit B_{12}	Vit C
VEGETABLES																			
Nightshade	2.9	64	11	1	3.2	11	4.1	4.1	0	220	185	31	2.9	9.3	32	12	12	0	638
Spinach	3.2	40	6.7	0.8	1.9	7	2.0	1.9	0	280	128	22	2.56	6.08	22.4	6.24	6.208	0	896
Swiss chard	3.2	28	4.7	0.3	1	6	0.8	0.52	0	240	89	15	0.96	3.2	19.2	2.56	1.664	0	768
Cabbage	12	0.4	0.07	0.4	0.2	3	0.8	0.16	0	300	4.9	0.861	4.92	2.46	36.9	9.84	1.968	0	3690
FRUIT																			
Mango	5.1	3.9	0.66	0.6	0.3	7	0.7	0.4	0	310	20	3.366	3.06	1.53	35.7	3.57	2.04	0	1581
Melon	5.3	6.9	1.2	0.4	0.1	7	0.4	0.22	0	390	37	6.148	2.12	0.53	37.1	2.12	1.166	0	2067
LEGUMES																			
Peanuts	0.4	-	0.0	6.4	1.4	121.0	3.5	2.4	0.0	0.0	-	0.000	2.8	0.6	52.0	1.5	1.0	0	0
Beans, dried	0.5	-	0.0	6.5	2.3	21.0	4.4	3.7	0.0	30.0	-	0.000	2.9	1.0	9.5	2.0	1.7	0	14
Beans, broad	0.6	-	0.1	5.6	3.3	28.0	3.7	4.2	0.0	10.0	-	0.000	2.5	0.7	13.8	2.4	2.0	0	17
Chick peas, dried	0.2	-	0.1	4.8	2.1	15.0	5.3	5.6	0.0	40.0	-	0.009	1.0	0.6	5.0	0.7	0.8	0	2
Lentils	0.7	-	0.1	3.7	2.2	20.0	-	-	-	-	-	0.046	3.1	1.4	9.8	3.5	3.6	0	26
Peas, split	0.2	-	0.2	7.3	2.2	29.0	1.7	2.7	0.0	20.0	-	0.011	0.7	0.4	3.6	-	-	-	-
Soybeans, dried	0.7	-	0.2	8.7	8.7	16	3.8	3.7	0.0	60.0	-	0.108	5.3	1.6	20.9	1.3	2.0	0	14
GRAINS																			
Maize	1.1	-	2.8	2.0	0.6	17.0	0.1	0.5	0.0	70.0	-	1.1	8.3	2.5	70	0.2	1.9	0	289

Pumpkin L.* Pumpkin leaves, H. squash* Hubbard squash, OFSP* Orange fleshed sweet potato, C. cabbage* Chinese cabbage (*Brassica rapa L subsp. Chinensis*), Cowpea L.* Cowpea leaves

Micro-nutrient water productivity

Micro-nutrient water productivities for several nutrients are set out in detail for several food products in Tables 6.17 and 6.18. There are clearly wide ranges within most of the different food groups, most likely as a result of environmental influences on water productivity and nutrient content, and because of the questionable reliability of calculating NWPs with independent water use efficiency and nutrient content data sets. A summary of iron and vitamin A water productivities for the different food groups studied is presented in Table 6.19.

Table 6.19: Nutritional water productivities for iron and vitamin A

Product type	Iron (mg m^{-3})	Vitamin A (mg Re m^{-3})	β-carotene (mg m^{-3})
Animal products	1.3-18	0.01-1.3	0
DGLV*	7.6-316	0.17-37	0.95-221
Yellow / orange vegetables	9-84	3-46	12-2226
Other vegetables	3-317	0.1-59	5-351
Fruits	10-21	0.5-6.1	2-37
Legumes	12-40	0.01-0.11	-
Grains	21	1.1	0

***** DGLV = dark green leafy vegetables

Some of the vegetable crops, especially the dark green leafy ones, appear to be efficient iron accumulators, but it is pointed out in Chapter 5 that one needs to take into account the form of iron (haeme vs. non-haeme), and concurrent absorption-promoters and -inhibitors in the diet. The yellow/orange vegetables are particularly efficient producers of β-carotene, but many of the other vegetable crops are also quite good sources of this pro-vitamin. Although animal products are rich in Vitamin A, it is more water efficient to produce this nutrient with fruits and vegetables according to these calculations.

As far as Zn is concerned, maize exhibited an intermediate nutritional water productivity (18 mg m^{-3}), fruit was low (3-6 mg m^{-3}), and carrots (49 mg m^{-3}) and some vegetable's leaves (pumpkin leaves 38, amaranth 33, beetroot leaves 36 mg m^{-3}) were high. Zn water productivity of animal products were quite low for chicken, pork and eggs (2.5-6.2 mg m^{-3}), intermediate for milk (11 mg m^{-3}), and relatively high for the larger stock (13-26 mg m^{-3}).

6.4 DISCUSSION, IDENTIFICATION OF KNOWLEDGE GAPS AND CONCLUSION

The main aim of this chapter was to document **water use efficiency** of selected important unprocessed crop and animal food products, and then to use these with nutritional values to make first order estimates of **nutritional water productivity** of these food products.

A brief review of the principles influencing WUE was given to put into context the published values found in the literature. There is much variation in these values, and limited data for many important foods.

It is important to appreciate that it is not a trivial exercise to quantitatively assess the water use of a crop, or the water needed to produce a unit of animal product. There are many factors that need to be taken into account in order to determine if published values are reliable and can be trusted, and this needs some experience. There are also many factors that affect the efficiency with which water is converted to food, and for this reason, very large variations in published values were found for most food products. Several biophysical principles were explained in simple terms in order to make it easier to understand and explain observed values and trends in the published data.

A general ranking of water use efficiency of crop products, from most to least efficient, would be from vegetables to fruits, and on to cereals, oil crops and protein rich legumes. However, this ranking is not quite fair, as water content of the product is not always explicitly mentioned, and the composition of the food is ignored if we only consider dry mass. The animal derived products are shown to be less efficient than the crops, and the ranking, again from highest to lowest, is from milk and eggs, to chicken and pork, and on to small stock (sheep and goats) and then beef. The water used for drinking purposes is negligible if compared to that required to produce livestock feed. The concept of "green" and "blue" water is also briefly discussed, as it is important to realise that under certain circumstances, the production of seemingly inefficient animal food products, may make perfect sense.

Reliable local "water footprint" data is lacking for most of the important food crops investigated, and research is needed on priority foods in areas of need. Research should focus on benchmarking potential yields and water use efficiencies, so that suboptimal performance can be identified, and limiting factors for production or efficiency addressed.

Initial benchmark estimates of **nutritional water productivity** for key nutrients of selected crops (cereals, legumes, fruit, dark green leafy vegetables, and yellow/orange vegetables) and animal food products were made, and an attempt was made to put these in perspective with a brief discussion of the results, and here we also highlight possible future research needs.

Published literature for NWP of crops and animal food products for South Africa is limited, and we could not find data to make the calculations for many of the selected food products. The estimates of nutritional water productivity came from two independent data sources – one a crop water productivity database, and the other a nutritional content database, both with some level of uncertainty, and of additional concern is the reliability of using these two independent data sets to generate a third database – one of nutritional water productivity. This is clearly not ideal, but was the only pragmatic approach open to the research team to come up with first order estimates of NWP for important food products.

For all food products there is a wide range in nutritional water productivities, probably due to the errors committed with making calculations with two independent data sets – this is problematic, and it is clear that we need to encourage these calculations to be made with single reliable data sets.

Energy Most food groups had products that seemed to be quite energy efficient in terms of water consumed per MJ produced, with the exception being the animal derived products. Here it is important to take into account that natural veldt (use of green water), can typically only be utilised for animal production. Crops with high efficiencies were maize (17.3 MJ m^{-3}), mango (15 MJ m^{-3}), cabbage (17 MJ m^{-3}), the dark green leafy vegetable (DGLV) amaranth (32 MJ m^{-3}), the yellow / orange vegetables – carrots, sweet potatoes and pumpkins (24 MJ m^{-3}), and leguminous crops – soybeans and groundnuts (11 MJ m^{-3}).

Protein and Fats Despite animal products being relative rich protein and fat sources, their large water footprints make them relatively inefficient sources of these nutrients (chicken and pork most efficient at around 60-70 g m^{-3}). It is interesting to note that some of the DGLV's appear to be exceptionally efficient protein synthesisers (pumpkin leaves 608 g m^{-3} and amaranth at 578 g m^{-3}). The leguminous crops are quite efficient protein and lipid synthesisers, with soybeans exhibiting a protein water productivity of 177 g m^{-3}, and groundnuts a protein and fat water productivity of 111 and 212 g m^{-3} respectively. Maize was also very efficient (132 g protein m^{-3} and 50 g fat m^{-3}), and some of the orange/yellow vegetables and other vegetables did quite well too (pumpkin 152 and cabbage 185 g protein m^{-3}). Fruit are poor sources of protein, and as expected their nutrient productivities were very low.

Vitamin A and iron Some of the vegetable crops, especially the dark green leafy ones, appear to be efficient iron accumulators, but it is pointed out that one needs to take into account the form of iron (haeme vs. non-haeme), and concurrent absorption-promoters and -inhibitors in the diet. The yellow/orange vegetables are particularly efficient producers of β-carotene, but many of the vegetable crops are also quite good sources of this pro-vitamin. Although animal products are rich in Vitamin A, it is more water efficient to produce this nutrient with fruits and vegetables according to these calculations.

Future research We suggest that research should be done on selected important food products that would involve the determination of potential yields and water use efficiencies, whilst simultaneously determining the nutritional value of the produce in order to determine actual measured nutritional water productivity benchmarks under a range of production conditions for key nutrients. This would encourage the identification of limiting factors to attaining efficiency goals under field conditions.

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CHAPTER 7
CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

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7.1 CONCLUSIONS IN RELATION TO STUDY OBJECTIVES

The aim of this desktop study was to determine, as part of a scoping study, nutritionally important foods for the diet of rural households in South Africa with specific reference to the poor. In addition we aimed to describe the nutrient content and water use of related unprocessed crop and animal food products using existing knowledge. Guided by the specific objectives of the study (see Chapter 1) the following sections highlight the respective conclusions, outline where shifts in emphasis were necessary and summarise knowledge gaps. This is followed in section 7.1.8 by integrated conclusions of the project as a whole.

7.1.1 Contemporary food basket (food intake) across seasons of poor households in rural areas

Several studies reported food intake data, but with the exception of the National Food Consumption Survey (NFCS), most studies were not designed to collect representative food intake as the main objective. Comparability among studies and merging of food intake data were limited because dietary assessment and reporting were not harmonised. Because of the limited information available and the non-representativeness of small-scale studies, we were not able to compile a food basket for the rural poor. We did, however, compile lists of foods mostly consumed for specific sites within provinces. The general trend was that current food intake is mostly cereal-based, with low intakes of fruit, vegetables and foods of animal origin. In Limpopo Province, intakes from green leafy vegetables appear to be higher than for the other provinces. A poster visually summarises the commonly consumed foods in South Africa, nationally and by province (Appendix A).

7.1.2 Sources of components in the food basket (food intake) across seasons

According to the National Food Consumption Survey-Fortification Baseline (NFCS-FB) of 2005, South Africans buy maize, wheat and bread and, at the national level, purchasing seems to be the most important source of these staple foods. Few small-scale studies reported on food sources, providing some evidence of home or community gardens, but there are insufficient data for generalisation. Regarding the foods of which intakes appear to be low (foods of animal origin, fruit and vegetables) and which could potentially be home-produced, there is limited evidence of source, including seasonality.

7.1.3 Nutritional gaps in the food basket (food intake), key nutrients and recommended foods and / or crop / animal products for household food and nutrition security

Generally, consumption of foods of animal origin, fruit and vegetables is low; resulting in inadequate intake of various micronutrients, low nutrient density and lack of dietary variety. Based on dietary as well as biochemical indicators, key micronutrients lacking in the diet are vitamin A, iron and zinc. Several studies have reported low energy intakes, while total protein intake seems to be adequate.

It is stated that no single food can ensure nutritional adequacy and dietary quality. Variety, balance and moderation remain the pillars from a nutritional perspective. In addition, availability, affordability and acceptability are essential for a sustainable solution for nutrition (in)security. The process followed to derive project-specific criteria for the compilation of food selection guidance is described, focusing on potentially home-producible foods by the rural poor of South Africa. The list of foods compiled consists of animal-source foods, vitamin A and mineral-rich vegetables and fruit, legumes, staples, and cabbage as control.

7.1.4 Nutrient content of selected unprocessed crop and animal food products for human consumption

Because of the knowledge gaps in terms of foods consumed and food source for the rural poor, the compilation of a definitive food basket was not feasible. Instead, we produced “food selection guidance” specifically for this project, which represents a list of foods that could potentially be produced as household level, and for which water use should be determined by the agronomists in the team. The nutrient content of foods listed was obtained from the South African food composition database, reported per 100g raw, edible portion. Nutrient values in any food composition database are always estimates, and should be interpreted as such.

7.1.5 Reasons for the contemporary food basket (food intake) of households at different poverty levels in rural areas

Few of the studies reviewed specifically indicated how poverty was defined and even fewer definitions and indicators were comparable across the various studies. Rural is generally ill-defined and often taken to be synonymous with poverty, ignoring the socioeconomic diversity that prevails in rural areas. Very few studies actually focused on the question of food intake and the reasons for contemporary food intake patterns amongst South Africans. While we were able to identify some of the reasons for contemporary food intake, specifically the multiple factors within the physical, economic, social and individual environments, the reviewed studies do not enable us to make comparisons across field sites, groups of people, socioeconomic levels or to draw representative conclusions in any way. At best the data provides many of the possible factors that play a role in determining individual food intake but we have now idea of the significance of any of these within certain geographical locations, for various households, specific groups of the poor and for individuals. None of the existing national household surveys, such as the Income and Expenditure Survey, General Household Survey and the various nutrition surveys even consider reasons for food intake and therefore do not contribute to our understanding of factors mitigating the intake of nutritious food.

The current study identified a number of crucial gaps in our knowledge on food intake that require deeper investigation. Firstly, there is a paucity of studies focusing on the reasons for contemporary food intake by rural households across South Africa. Since most studies are on micro-level there is only limited information on food choices for sampled households within specific study villages. Secondly, there is little information about the hierarchy of reasons for food choices. Thirdly, the oversimplification of ethnic diversity into categories of race in many of the studies result in a loss of cultural diversity, emphasises distinctions that in reality may not exits and ignores the interplay of other often more influential contributing factors – such as income, location, availability, perceptions of ‘modern’, religion, etc. – which ethnographic studies confirm. Fourthly, seasonality is extremely under-researched, specifically with regard to food availability but also with respect to production, employment, migration, household food needs and the ability of households to purchase food. Fifthly, the impact of HIV/AIDS on food choices is limited to its impact for harvesting in the wild. More in-depth work is required around other coping strategies and ways of accessing food, especially when the social, physical and natural resource environment may not be conducive to harvesting in the wild on communal lands. Sixth, the contribution of social networks (rural working parties) and social events (weddings, funerals, and other rites of passage) to food security is seldom considered and therefore inadequately documented in food security studies. Seventh, individual responses to intra-household allocation of food are also ignored in the existing literature, with the exception of some research on children who harvest in the wild. Finally, if one compares the early ethnographies on social and cultural systems in the early part of the 20th century with existing studies, the reasons for food intake and the type of food consumed is seldom documented and validated from a social science perspective. For example, no studies were identified that consider the impact of social transformations during the past two decades on food consumption patterns and the reasons therefore. The contemporary reasons for food intake amongst the poor in South Africa are extremely under-researched. It is vitally urgent that this situation changes in order to inform any foods based approach to improving the food and nutrition insecurity currently experienced in rural areas.

7.1.6 Water use of selected unprocessed crop and animal food products for human consumption

Not surprisingly, a great deal of variation was found in the water use of the crop and animal food products contained in the food selection guidance, with limited data for many of the foods. It is not altogether a trivial exercise to quantitatively assess the water use of a crop, or the water needed to produce a unit of animal product, and there are many factors that need to be taken into account in order to determine if published values are reliable and can be trusted. It is also important to discriminate between “green” and “blue” water consumption of food products.

A general ranking of water use efficiency of crop products that ignores water content and composition, from most to least efficient, would be from vegetables to fruits, and on to cereals, oil crops and protein rich legumes. The animal derived products are shown to be less efficient than the crops, and the ranking, again from highest to lowest, is from milk and eggs, to chicken and pork, and on to small stock (sheep and goats) and then beef.

Specific values found in this study showed that Dark Green Leafy Vegetables (DGLVs) had quite high *dry mass* WUEs of around 10-30 kg ha^{-1} mm^{-1}, as harvest index is high and protein content low. The yellow / orange vegetables, which are usually rich sources of vitamin A, also showed large variations in published WUE values. It is important to note these values were on a *wet mass* basis, and therefore appear much higher than those of the DGLVs. Carrots were as high as 148, sweet potato 130 and pumpkins 266 kg ha^{-1} mm^{-1}. Leguminous crops are protein rich so we expect their water use efficiencies on a dry mass basis to be low, and values are around 3-6 kg ha^{-1} mm^{-1} for most of the bean species. The grain crops are energy rich, and WUE values reported for maize and sorghum ranged from 4 to 16 kg ha^{-1} mm^{-1}. The wide range of values results from variations in crop management, soil fertility, climatic conditions and other factors which affect crop growth and water productivity. For fruit crops, maximum WUEs were around 70 kg ha^{-1} mm^{-1} on a wet mass basis, substantially lower than for some of the vegetable crops. This is to be expected, as trees need to invest in structures to hang the fruit, and harvest index is therefore lower. Mango appeared to have a high WUE, but food composition is important to take into account, with the high oil content of avocados depressing this fruit's WUE. Finally, well managed vegetable crops had very high fresh mass WUE values of as high as 327 kg ha^{-1} mm^{-1} for green peppers and cabbage, and potato had a WUE of 161 kg ha^{-1} mm^{-1}.

7.1.7 Estimated benchmarks of nutritional water productivity for key nutrients of selected crop and animal food products

Initial benchmark estimates of nutritional water productivity (NWP) for key nutrients of selected crops (cereals, legumes, fruit, dark green leafy vegetables, and yellow / orange vegetables) and animal food products were made.

Published literature for NWP of crops and animal food products for South Africa is limited, and for many of the items in the food selection guidance products, no data could be found to make the calculations. The estimates of NWP came from two independent data sources – one a crop water productivity database, and the other a nutrient composition database, both with some level of uncertainty. Of additional concern is the reliability of using these two independent data sets to generate a third database – one of NWP. This is clearly not ideal, but was the only pragmatic approach open to the research team to come up with first order estimates of NWP of macro- and micro nutrients for important food products. For all food products there was a wide range in nutritional water productivities, probably due to the errors committed with making calculations with two independent data sets – this is not ideal, and it is clear that we need to encourage these calculations to be made with single reliable data sets.

Macronutrients. Most food groups had products that seemed to be quite energy efficient in terms of water consumed per MJ produced, with the exception being the animal derived products. Here it is important to remind ourselves about the use of natural veldt, which can only be utilised to produce animal products (use of so called green water), so one needs to be cautious not to outright discourage the production of these food sources solely on their low water use efficiencies. Crops with high efficiencies in this study were maize (17.3 MJ m^{-3}), mango (15 MJ m^{-3}), cabbage (17 MJ m^{-3}), for the DGLV amaranth (32 MJ m^{-3}), yellow/orange vegetables – carrot, sweet potato and pumpkin (24 MJ m^{-3}), and leguminous crops – soybeans and groundnuts (11 MJ m^{-3}). Despite animal products being relatively rich protein and fat sources, their large water footprints make them relatively inefficient sources of these nutrients (chicken and pork most efficient at around 60-70 g m^{-3}). It is interesting to note that some of the DGLVs appear to be exceptionally efficient protein synthesisers (pumpkin leaves 608 g m^{-3} and amaranth at 578 g m^{-3}). The leguminous crops are quite efficient protein and lipid synthesisers, with soybeans exhibiting a protein water productivity of 177 g m^{-3}, and groundnuts a protein and fat water productivity of 111 and 212 g m^{-3} respectively. Maize was also very efficient (132 g protein m^{-3} and 50 g fat m^{-3}), and some of the orange/yellow vegetables and other vegetables did quite well too (pumpkin 152 and cabbage 185 g protein m^{-3}). Fruit are poor sources of protein, and as expected their protein water productivities were very low.

Micronutrients. The micronutrients that received the most attention were vitamin A, zinc and iron. Some of the vegetable crops, especially the DGLVs, appear to be efficient iron accumulators, but it is important to take into account the form of iron (haeme vs. non-haeme), and concurrent absorption-promoters and -inhibitors in the diet. The yellow/orange vegetables are particularly efficient producers of β-carotene, but many of the other vegetable crops are also quite good sources of this pro-vitamin. Although animal products are rich in Vitamin A, it is more water efficient to produce this nutrient with fruits and vegetables. As far as zinc is concerned, maize exhibited an intermediate nutritional water productivity (18 mg m^{-3}), fruit was low (3-6 mg m^{-3}), and carrots (49 mg m^{-3}) and some vegetables leaves (pumpkin leaves 38, amaranth 33, beetroot leaves 36 mg m^{-3}) were high. Zinc water productivity of animal products were quite low for chicken, pork and eggs (2.5-6.2 mg m^{-3}), intermediate for milk (11 mg m^{-3}), and relatively high for the larger stock (13-26 mg m^{-3}).

7.1.8 Integration

As maize is predominantly bought, and foods of animal origin, vegetables and fruit are limited in the diet, local food production in rural communities should focus on home/community gardens to produce micronutrient rich foods to supplement the predominantly cereal based diet. Sustainable food production is dependent on a continuous supply of water for irrigation, which could be a limiting factor in rural areas. Amongst others, factors that will determine whether home production will be able to produce a consistent supply of micronutrient rich foods include seasonality, crop selection, land and water availability, knowledge about production, and an enthusiasm to produce.

Working across disciplines is critical if we wish to improve household food security of the rural poor. It does, however, also come with its challenges. Between nutrition and agronomy, two key challenges were experienced in this study. Firstly, the two disciplines view macro- and micronutrients differently. Secondly, nutritionists expresses nutrient content of food as amount of nutrient per 100 g fresh edible portion, whereas agronomists express yields of agronomic crops on a dry mass basis, but horticulturalists often express fruit and vegetable yields on a fresh mass basis. These may seem trivial differences between disciplines, but much confusion arose between the teams when working together on this topic. It also highlights the power of the concept of nutritional water productivity, as this calculation is explicit and quantitatively expresses the amount of water used to produce a unit of macro- or micro-nutrient, without the water content of the food in question confusing the interpretation of these values, as occurs with water use efficiencies of food products of varying water contents.

7.2 RECOMMENDATIONS

Based on our learning during the study and the knowledge gaps that were identified, discipline-specific and trans-disciplinary recommendations for future research have been identified.

7.2.1 Discipline-specific recommendations for future research

7.2.1.1 Human nutrition

We were unable to compile a food basket for the rural poor for several reasons, one being the non-uniform format in which food intake data are reported in the literature. Dietary surveys are expensive and labour intensive, and they require expertise in dietary assessment and access to software for dietary analysis. With the exception of the NFCS, very few studies, if any, were designed with the sole purpose of assessing dietary intake. In order to improve uniformity across studies reporting food intake, we propose the development of a guide for reporting food intake data in a comparable manner and which will allow for the compilation of a food basket.

In relation to the behavioural side of nutrition research, a behavioural theory-based investigation (for example using the Health Belief Model or the Trans-theoretical [Stages of Change] Model) of how attitudes and beliefs related to food, nutrition and health influence the eating behaviour of the rural poor of South Africa, would yield much needed information for promoting behaviour change. By increasing our understanding of the basic mechanism(s) of behaviour and behaviour change in this vulnerable group, behavioural theory-based nutrition research has the potential to increase efficiency and efficacy of agricultural interventions (e.g. the adoption of home-production and consumption of specific crops, or the adoption of specific irrigation/rain-water harvesting practices).

In the context of nutrition-sensitive agricultural interventions, there are two major gaps in the current literature namely

(i) what is the contribution of home / smallholder grown foods to total dietary intake and nutrient requirements (in the context of an in-depth description of the food environment and its linkages to water), and

(ii) what is the effect of seasonality on home / smallholder production and resultant food intake?

The above can be applied in general to the rural poor, or to specific contexts, e.g. public schools where the National School Nutrition Programme (NSNP) is implemented, with the aim of strengthening the third pillar of the NSNP, i.e. sustainable food production in the community. During a recent, official "SWOT" analysis of the NSNP with staff of the National Department of Basic Education, the need for such supportive research was implied.

Other questions in this context that come to mind are related to the optimal water and fertilizer usage for optimal nutrition content of crops in the South African context.

Graphically, the research chain for agriculture and nutrition is depicted in Figure 1 (adapted from Hawkes et al, 2012). We recommend that water as a "blue, connector-thread" among the various practices, impacts and outcomes be investigated.

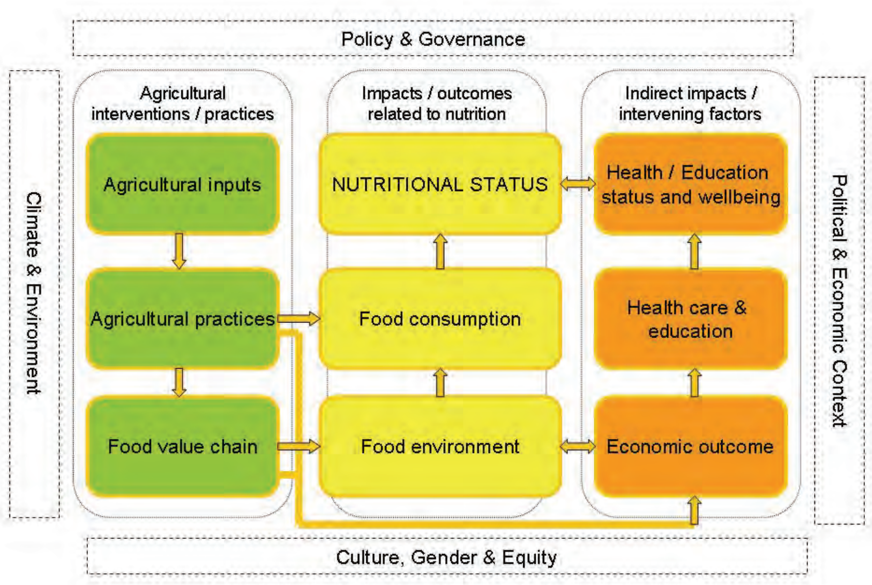

Figure 7.1 The research chain for agriculture and nutrition (adapted from Hawkes et al, 2012)

7.2.1.2 Sociology

Given the paucity of research on the topic of food choices, numerous sociological studies could be conceived to contribute to the overall shortage of data as well as in conjunction with economic, nutrition and agricultural studies in order to supplement the data gathered during these more regular food and nutrition studies. Here we simply propose two possible sociological studies that could stand alone and also contribute to increasing knowledge about water-use and home garden production of food. Both proposed studies would involve participant observation and ethnographic fieldwork at no more than four field sites.

Firstly, because water is vital to crop and livestock production, a useful sociological study would focus on the socio-political factors affecting the access to water for home-garden food production. This would specifically consider why some households seem to have ready access to water and others do not. Socio-political, rather than physical and economic factors might explain why some people produce on home gardens and others do not. Of interest here would also be how these socio-political factors contribute to the vulnerability of potential agricultural water users in rural South Africa. A key question would be, does water access influence home-garden production, how does it do this and what role do socio-political factors play in the process of water access and food production? Such a study could also be extended to include the influence of such factors to accessing water from irrigation schemes and systems.

A second sociological oriented study would consider the significance of water access to determining food intake patterns amongst rural households across several seasons. This would specifically consider the interplay of various factors outlined in Objective 4 of this study. However, the focus would be on examining the link between water use for food production and various socio-cultural and socioeconomic factors. Factors of interest include, but are not confined to, periods of high household demand for food, labour availability for production, health status, cultural influences, migration, economic circumstances, and social obligations.

7.2.1.3 Agronomy

Reliable local "water footprint" data are lacking for most of the important food crops investigated, and research is needed on priority foods in areas of need. Research should focus on benchmarking potential yields and water use efficiencies, so that suboptimal performance can be identified, and limiting factors for production or efficiency addressed.

For all food products there is a wide range in NWPs, probably due to the errors committed with making calculations with two independent data sets – this is problematic, and it is clear that we need to encourage these calculations to be made with single reliable data sets.

It seems that the nutritional water productivity focus needs to be on irrigated horticulture – the vegetable and fruit crops that can provide the key micronutrients lacking in the diets of the rural poor. In particular, attention should be paid to dark green leafy vegetables and yellow / orange vegetables. There is likely also scope for research on bio-fortification of crops through the use, for example, of zinc and iron foliar sprays and soil amendments.

7.2.2 Recommendations for inter-disciplinary future research

7.2.2.1 Recommendation 1

Early in the project it became apparent that very little baseline information regarding food consumption and the sources of food (see Chapter 3 and above 7.1.1 and 7.1.2) is available. Hence the WRC solicited a follow-up project which focussed on **Rain-fed and irrigated production of food crops and their potential to meet the all year nutritional requirements of rural poor people in South Africa.** The rationale of this follow-up study (taken from the terms of reference – see Appendix E) follows:

"In the biannual *Overview of the World Food Situation* by the International Food Policy Research Institute (IFPRI) at the end of 2007, it is stated that renewed attention must be given to agriculture, nutrition and health in adjusting research agendas. Strategies must be directed at poor members of society. In this regard social security measures must be taken that focus on early childhood nutrition, particularly poor households. With increasing risks caused by climate change, more investment must be made in agriculture to improve productivity. This includes investment in agricultural science and technology to facilitate a production response to rising food prices.

At a conference on Nutrition and Food for Special Dietary Uses at the beginning of November 2008 in Cape Town, the South African Minister of Health stated that "…food insecurity and high rates of malnutrition, coupled with high food prices, remain the biggest threat to nutrition in Africa". More research is thus needed in support of programmes that will improve health through balanced nutrition and the availability of food at reasonable prices.

The WRC solicited project titled "A baseline and scoping study on water use and nutrient content of crop and animal food products for improved household food security" (WRC project No. K5//1954/4) identified insufficient data on food intake of poor households in rural areas of South Africa. The study also found that very little information is available on the sources of foods consumed by rural households. This means that overall, insufficient data are available to make generalisations about the "basket" of foods and the source of foods of the rural poor in this country, and consequently it is difficult to develop appropriate programmes that will improve the nutritional health of rural communities.

Although dietary studies indicate that rural poor people meet very little if any of their nutritional requirements through own food production, this is contradicted by case study evidence from an agricultural perspective. It is therefore necessary to undertake empirical research on food production and intake of poor households. Given the increase in food prices and high rates in malnutrition, this research can contribute to alleviating household food insecurity as well as the nutrition problems amongst the rural poor. Opportunities exist that some of the foods in a balanced diet can be produced in gardens or field plots, which are currently underutilised. The provinces of North West, Limpopo, KwaZulu-Natal and Eastern Cape have been prioritised because this is where the majority of rural poor people live and produce crops under rain-fed and irrigated conditions and potential exists to enhance production. It is important to identify the food crops for detail follow-on research of water use and nutritional productivity for the purpose of reducing under-nourishment and increasing household food security."

7.2.2.2 Recommendation 2

During a final meeting of project team members the need for another interdisciplinary follow-up research study arose. It was broadly titled "**Improving nutritional water-productivity of home-grown crops in rural poor communities**". An outline follows:

The current study was unable to make generalisations about the contemporary food basket (food intake) and food procurement of the rural poor, because of insufficient available data. Furthermore, the lack of information means that it is unclear in most instances as to what extent the various and changing environments influence food choices, nutrient intake and the contribution of home-garden production to food and nutrition security. This hinders the development of appropriate and sustainable nutritional, social, agricultural and integrated programmes that will improve the nutritional health of rural communities.

Although dietary studies indicate that rural poor people meet very little if any of their nutritional requirements through own food production, this is contradicted by case study evidence from an agricultural perspective. Furthermore, the current study suggests that while staples might be purchased fairly regularly, vegetables are often produced in home-gardens on a seasonal basis or harvested in the wild. Aliber (2009) has indicated that the vast majority of those engaged in some form of agriculture do so to supplement household food supply. With the continuous increase in food prices, it is foreseen that the rural poor will in future rely to a greater extent on home production for household food and nutrition security. Home gardens for nutritional benefits are, however, underutilised because of sub-optimal gardening practices. Current home production systems can be improved through (i) careful selection of a variety of nutrient-rich crops (to overcome seasonality, increase dietary variety, increase nutritional adequacy of the diet) and nutrient intake, and (ii) manipulating agricultural practices (e.g. water application and fertilization) to extend the yield and harvesting period. Nutritional water productivity strategies for home-grown crops within certain rural environments should thus be identified and strengthened. The provinces of Limpopo, KwaZulu-Natal, Eastern Cape and North West have been prioritised because this is where the majority of rural poor people live and produce crops under rain-fed and irrigated conditions and potential exists to enhance production. To be able to show that improved agricultural practices can impact on food consumptions patterns, dietary intake and nutritional status, suitable control sites (with a delayed implementation – for ethical reasons) are needed.

It is proposed that action research be adopted as an overarching approach of understanding more about the nutrition-related needs of the rural poor, their food procurement and consumption choices and as a means of identifying and in-field strengthening of the preferential nutritional water productivity strategies that should be adopted for home-grown crops within certain rural environments. The role of action research in developmental situations is increasingly acknowledged (Greenwood and Levin, 2007). One of the core advantages of the approach involves collaboration between researchers and local stakeholders with the identification, understanding, resolution and evaluation of existing problems. Amongst other additional advantages, it also allows for the inclusion of quantitative sub-studies (mixed-method: concurrent, nested design [Creswell 2003:213-214]).

While it is proposed that the three disciplines of human nutrition, sociology and agricultural science work together to assist poor rural households in producing nutritious home-grown crops based on NWP, in terms of local water availability, it is acknowledged that some discipline specific research will be required. Agricultural scientists will, for example, consider current crop suitability, introduction of new varieties, and effectiveness of current farming practices including irrigation, soil conservation and fertilisation techniques. Nutritional scientists will obtain nutritional baseline data, food consumption practices and monitor nutritional status and may conduct (controlled) intervention studies. The sociologists will focus on the social and economic circumstances, food and cultural linkages, food consumption behaviour, and factors influencing vulnerability to food and nutrition security. Discipline specific studies will be designed collaboratively and will be used to inform the action research process. For example, all three disciplines and local participants will be involved in identifying suitable nutritious foodstuffs that can be produced in home-gardens across seasons under the prevailing socioeconomic and agroecological circumstances, to ensure a sustainable supply of micronutrient rich foods. Furthermore, for example, all disciplines will be involved in understanding the prevailing local or indigenous knowledge use in food procurement (production, purchase, exchange, hunting and gathering), preparation and storage strategies and practices in order to see if necessary, where and how improvements can be introduced. Technologies and practices developed during earlier WRC research projects, such as rain-water harvesting, fertilisation, etc. can be tested in-field/on-site with the collaboration of local participants.

The action research project proposed here could stand alone and be implemented in two or three newly identified rural research areas, or it could be implemented within one or two of the rural areas that form part of the solicited project noted above in Recommendation 1. In the latter instance, the proposed study could utilise some of the baseline information obtained as part of the study identified as Recommendation 1. This would reduce some of the data collection in the first phase and would enable some feedback of the interim findings of Recommendation 1 to the involved rural communities and local stakeholders.

7.3 FINAL REMARK

Since the starting point and rationale for this study was the plight of the rural poor, the process can only be complete if we return to the point of departure. This would be our ultimate recommendation.

I was hungry and you formed a committee to investigate my hunger;

I was homeless and you filed a report on my plight;

I was sick and you held a seminar on the situation of the underprivileged;

you investigated all aspects of my plight yet I am still hungry, homeless and sick.

(T L V Ulbright)

7.4 REFERENCES

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APPENDICES

Appendix A: Food Intake South Africa (Replica of A1 Poster)

Appendix B: Slides from a PowerPoint teaching Aid

Appendix C: School-based vitamin A promotion: Visual communication as part of an Information Design project: Images from an indirect capacity development initiative

Appendix D: Popular article: Water Wheel; March /April 2012 (p 30-31)

Appendix E: Terms of reference for a follow-up project

HSRC
Human Sciences
Research Council

MRC
SOUTH AFRICA

fewer drops
more crops
most nutrition