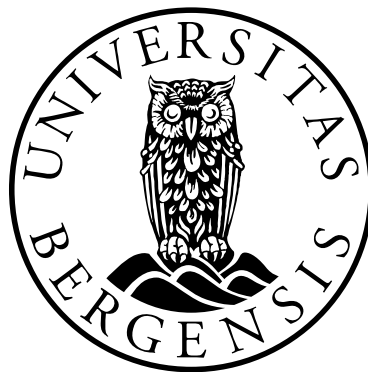# Determinants of child malnutrition

Studies from a rural area in the Democratic Republic of Congo

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Dissertation for the degree of philosophiae doctor (PhD)
at the University of Bergen

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In memory of Professor Jan Van den Broeck

Scientific environment

My workplace has been the Centre of International Health (CIH) throughout the whole project period. The institutional framework for the research environment of this study was provided by cooperation between CIH and the School of Public Health, University of Kinshasa.

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Acknowledgements

My thanks go to the people in Bwamanda who took their time to participate in the study.

This thesis is dedicated to my supervisor Jan Van den Broeck who died in November 2014. He introduced me to Bwamanda, to epidemiology and nutrition. Thanks also to my other supervisor Karen Marie Moland and to Anne Hatløy who became my supervisor in 2015.

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Abstract in English

Background

Child malnutrition in the form of stunting, wasting, underweight and clinical malnutrition has significant implications for healthy human development. As much as 45% of global child mortality can be attributed to child malnutrition. Marasmus and kwashiorkor, both clinical syndromes of severe child malnutrition have particularly high mortality rates. The Democratic Republic of Congo (DRC) is among the countries with the highest proportion of malnourished children in the world. This thesis contributes to the literature on child malnutrition by integrating the various determinants of child malnutrition and demonstrating how, in a specific local rural setting in the DRC, the interaction between dietary factors and social determinants have implications for children's nutritional status.

Methods

This thesis is based on a quantitative historical longitudinal study from 1989/90 and a qualitative contemporary household case study from 2012/13, both from Bwamanda, in north-west DRC. In the longitudinal study there was a total of 5567 children enrolled. Data collection was conducted during six quarterly survey rounds. The survey included assessment of children's nutritional status with clinical examination and a 24 hr. non-quantitative recall used to collect data about food items consumed by the children. The contemporary study recruited households with children with marasmus, households with children with kwashiorkor and households with well-nourished children. The methods used for data collection included participant observation, in-depth interviews, group discussion and key informant interviews.

Using data from the longitudinal study, the incidence of clinical versus anthropometrical malnutrition and incidence rates for different seasons, gender and age categories were compared. These data were also used to investigate the association between diet and the development of kwashiorkor and to compare the causal influence of dietary risk factors for kwashiorkor with those of marasmus. The household study data were used to explore links between individual child nutritional outcomes and processes at the local and macro socio-economic levels.

Results

This thesis combines a conceptual framework for malnutrition with social field theory in a multi-level analysis of nutrition.

At the immediate level, the study finds that in young children who were chronically malnourished the consumption of sweet potatoes, papaya and what is termed "other vegetables" reduces the risk of developing kwashiorkor. These food items contain β-carotene and the study proposes that food containing β-carotene plays an important role in protecting against kwashiorkor.

At the underlying level, the study examines household food security and social organisation of food production. Three social fields are associated with this level namely the household, inter-household cooperation (*gbisa*) and the village. The vulnerability of households to food insecurity and child malnutrition is related to household size and composition and ability to mobilise labour. Household's labour constraints could be solved by mobilising *gbisa.* It could also be organised for capital accumulation and used to further enhance livelihoods. There were transitory food security problems and the incidence of moderate clinical child malnutrition (McM) peaked in the pre-harvest period whereas the incidence of other forms of malnutrition was high in the rainy season. In this food insecure environment, young children below 24 months are at particularly high risk of malnutrition; after this age the risk dropped

Malnutrition in Bwamanda is closely related to distal macro socio-economic factors and the government's failure to stimulate growth in the small-scale subsistence agriculture sector has negative implications for child nutrition. A local NGO has filled the gap of public service but as a result of a decline in international funding the NGO has had to reduce its activities.

Conclusions

This study is probably the first observational longitudinal study to demonstrate a relationship between diet diversity and the development of kwashiorkor. The findings should be considered as supportive of on-going efforts to promote diverse agricultural and horticultural production and, in this manner, to stimulate consumption of a more varied diet that includes β-carotene. Nutrition programmes should address the problem of inequalities in service provision and make accessible social services that can improve food security and child

nutrition in households with few resources in the form of labour, land and capital. Institutions for inter-household cooperation should be involved to further improve food security and nutritional outcomes. Early-life interventions, adapted to the appropriate season and age, to ward off malnutrition is critical. The use of social field theory in the study of nutritional outcomes, as undertaken in this thesis, could be extended to the study of how social factors are associated with other health outcomes.

Abstract in Norwegian

Bakgrunn

Feilernæring blant barn har betydelige konsekvenser for sunn menneskelig utvikling i form av motorisk, kognitiv og sosial utvikling. Så mye som 45 % av global barnedød kan tilskrives feilernæring blant barn. Marasmus og kwashiorkor blant barn, begge former for alvorlig feilernæring, har spesiell høy dødelighet. Den Demokratiske Republikken Kongo (DR Kongo) er blant de landene som har høyest andel av feilernærte barn i verden. Avhandlingen bidrar til litteraturen om barneernæring ved å undersøke, med referanse til et spesifikt lokalsamfunn, hvordan samspillet mellom kostholdsfaktorer og sosiale faktorer har betydning for barnas ernæringsstatus.

Metoder

Avhandlingen er basert på en kvantitativ historisk longitudinell studie fra 1989/91,og en kvalitativ nåtidig husholdnings studie fra 2012/3. Begge studiene ble utført i Bwamanda. Den longitudinelle studien omfattet 5 567 barn. Datainnsamling ble utført i løpet seks kvartalsvise undersøkelsesrunder. Undersøkelsen inkluderte klinisk undersøkelse og vurdering av barns ernæringsstatus. I tillegg ble det samlet inn data om barns matkonsum. Husholdningsstudien tok for seg et utvalg av hushold med barn med marasmus, hushold med barn med kwashiorkor og hushold med vellernærte barn. Studien brukte deltakende observasjon, dybdeintervjuer og gruppediskusjon under datainnsamlingen.

Ved hjelp av data fra den longitudinelle studien, ble forekomst av klinisk versus antropometrisk definert feilernæring undersøkt. Studien sammenlignet forekomsten av feilernæring i ulike alderskategorier, samt sesongvariasjoner og varighet av feilernæring. Studien undersøkte også mulige sammenhenger mellom kosthold og utvikling av kwashiorkor, og sammenliknet risikofaktorer for utvikling av kwashiorkor med risikofaktorer for utvikling av marasmus. Husholdningsstudien ble brukt til å utforske sammenhengen mellom barns ernæringsmessige status, og prosesser på lokalt og makro sosio-økonomisk nivå.

Resultater

Avhandlingen bruker et konseptuelt rammeverk, som skiller mellom direkte, underliggende og grunnleggende faktorer, for å beskrive de innbyrdes årsakene til feilernæring. I analysen kombinerer avhandlingen dette konseptuelle rammeverk med sosial feltteori.

På det direkte nivået, viser funnene at blant unge barn som var kronisk feilernærte, så førte et lavt konsum av søtpoteter, papaya og det som ble kalt "andre grønnsaker" til økt risiko for å utvikle kwashiorkor. Disse matvarer inneholder β-karoten og studien antar at innholdet av β-karoten spiller en viktig rolle, og kan beskytte barn fra å utvikle kwashiorkor.

På det underliggende nivå undersøker studien matsikkerhet og sosial organisering av matproduksjon. Tre sosiale felt er assosiert med dette nivået nemlig husholdningen, husholdsamarbeid (*gbisa*) og landsbyen. Risiko for underernæring blant barn var knyttet til husholdningens størrelse og sammensetning og evne til å mobilisere arbeidskraft. Høyt arbeidspress kunne løses ved å mobilisere *gbisa* arbeidslag. *Gbisa* kunne også organiseres for kapitalakkumulasjon og brukes til og ytterligere styrke husholdenes økonomiske tilpasning Temporær matmangel var også et problem. Forekomsten av moderat klinisk feilernæring blant barn toppet seg i den tørre perioden før innhøsting av korn mens andre former for feilernæring var høy i regntiden. Studien antar derfor at forekomsten av feilernæring blant barn var knyttet til landbrukssesong og sesongmessige variasjoner i sykdomsmønstre. I dette samfunnet, preget av mangel på matsikkerhet var det en høy risiko for at små barn utviklet feilernæring. Barn under 24 måneder hadde en spesielt høy risiko, ved høyere alder minsket risikoen.

Avhandlingen undersøker grunnleggende determinanter for utvikling av feilernæring og knyttet feilernæring til den bredere samfunnsøkonomiske utvikling i DR Kongo. I Bwamanda har en lokal NGO tatt over mange av statens oppgave. Den har gitt støtte til jordbruksutvikling, og er ansvarlig for lokale helsetjenester. Som et resultat av redusert i internasjonal finansiering, har NGOen måtte begrense sin virksomhet. Studien viser dermed hvordan utviklingen av alvorlig feilernæring blant barn er relatert til nasjonale og internasjonale samfunnsøkonomiske forhold.

Konklusjon

Studien er trolig den første observasjons longitudinelle studie, som viser en sammenheng mellom kosthold og utvikling av kwashiorkor. Funnene bør betraktes som en støtte til pågående arbeid som tar sikte på å fremme et mangfoldig landbruk og hagebruk, og på denne måte stimulere til fremveksten av et mer variert kosthold. I rurale områder, der det er mangel på vitamin A rik mat, er det spesielt viktig å fremme økt produksjon av grønnsaker og frukt rik på karotenoider, inkludert søtpoteter og papaya. Institusjoner som arbeider med ernæring, bør ta opp problemet med ulikheter i tjenestetilbudet: De bør sikre at sosiale tjenester som kan forbedre matsikkerhet og ernæring, er tilgjengelig for husholdninger med få ressurser i form av arbeidskraft, land og kapital. Lokale institusjoner for husholdssamarbeid, bør involveres i arbeidet for og ytterligere forbedre matsikkerhet og ernæring. Avhandlingens tilnærming til bruk av sosial feltteori i studiet av ernæringsmessige utfall, bør også bli anvendt i studiet av hvordan sosiale faktorer er forbundet med andre helseutfall enn feilernæring.

List of publications

Paper I

Kismul H , Schwinger C, Chhagan M, Mapatano M, Van den Broeck J. "Incidence and course of child malnutrition according to clinical or anthropometrical assessment: a longitudinal study from rural DR Congo" BMC Pediatrics 2014, 14:22

Paper II

Kismul H, Van den Broeck J, Lunde, T M, "Diet and kwashiorkor: a prospective study from rural DR Congo" PeerJ 2014, 2

Paper III

Kismul H, Hatløy A, Andersen P, Mapatano M, Van den Broeck J, Moland K M. The social context of severe child malnutrition: a qualitative household case study from a rural area of the Democratic Republic of Congo, International Journal of Equity in Health 2015, 14(1): p. 47.

List of abbreviations

BMI: body-mass index

DRC: the Democratic Republic of Congo

DHS: demographic health survey

GDP: gross domestic product

HAZ: height for age z-score

IFPRI: International Food Policy Research Institute

IUGR: intrauterine growth retardation

McM: mild to moderate clinical malnutrition

MUAC: mid upper arm circumferences

LAC: Latin American and the Caribbean

LMIC: low and middle income countries

NGO: non-governmental organisation

PPP: purchasing power parity

UNDP: United Nations Development Programme

UNICEF: United Nations Children's Fund

WAZ: weight for age z-score

WHO: World Health Organization

WHO-MGRS: World Health Organization Multicentre Growth Reference Study

WHZ: weight for height z-score

Glossary

Accuracy; the accuracy of a measurement is its degree of closeness to that quantity's true value. Accuracy is associated with systematic errors

Clinical severe childhood malnutrition; a term used for the three clinical syndromes of clinical severe malnutrition including marasmus, kwashiorkor and marasmic kwashiorkor

Determinant; a factor related to an outcome such as a health outcome, used with or without any connotation as to whether the relationship is causal or non-causal

Hidden hunger; micro-nutrient deficiencies

Incidence; the number of new cases of a disease that occurs during a specific period in a population at risk of developing the disease

Kwashiorkor; a form of severe malnutrition where the presence of oedema is the most significant feature

Malnutrition; a condition that occurs as a consequence of consuming a diet that contains insufficient or too many nutrients or as a result of faulty digestion or utilisation of foods

Marasmic-kwashiorkor; a type of severe malnutrition and a mixed form of marasmus and kwashiorkor. It is characterized by the presence of both wasting and pitting oedema

Marasmus; non-oedematous severe child malnutrition and characterised by extreme wasting

Mid upper arm circumference (MUAC); in children, a MUAC between 11.0 and 12.5 cm indicates moderate malnutrition and a MUAC below 11.0 cm severe malnutrition

Obese; children with a BMI Z-score of 3 and higher

Overweight; children with a BMI Z-score of 2 to 3

Precision; the precision of a measurement is related to reproducibility and repeatability and is the degree to which repeated measurements under unchanged conditions show the same result. Precision is associated with random errors

Prevalence; the proportion of a population having a disease at a specific point in time

Sensitivity; of an indicator, the ability to identify and classify persons as having a disease

Specificity; of an indicator, the ability to identify and classify persons as non-diseased.

Stunted; children who have a HAZ-score of -2 to -3 are assessed as moderately stunted, and children who have a HAZ-score of -3 are assessed as severely stunted

Undernutrition; process of insufficient nutrient intake and / or nutrient absorption

Underweight; children with a WAZ-score of -2 to -3 are assessed as moderately underweight and of -3 or below as severely underweight

Wasted; children who have a WHZ-score of -2 to -3 are assessed as moderately wasted and a WHZ-score of -3 as severely wasted

Z-score; the number of standard deviations an element is from the mean

1. Introduction

1.1 The scope of this thesis

This thesis seeks to contribute to the literature on child malnutrition by integrating the various determinants of child malnutrition and demonstrating how, in a specific local rural setting, the interaction between dietary factors and social determinants have implications for children's nutritional status. It focuses on undernutrition and severe malnutrition in the form of marasmus and kwashiorkor.

Data analysis is structured by a conceptual framework for malnutrition that recognises determinants of malnutrition as operating at different levels including immediate, underlying and basic level. Social field theory is used as a tool for a theoretical multi-level analysis that uses qualitative data to identify social entities that have implications for nutrition.

This thesis uses data from a historical quantitative longitudinal study and a contemporary qualitative household study. Data were collected in Bwamanda, a rural area located in the north-west of the Democratic Republic of Congo (the DRC). The Ngbaka is the dominant ethnic group in Bwamanda and their principle livelihood is subsistence agriculture.

The introduction gives an overview of the problem and consequences of poor nutrition, regional disparities and selected determinants of nutrition with relevance for the topics addressed in the thesis.

1.2 Measuring malnutrition

Malnutrition is a condition that occurs as a consequence of consuming a diet that contains insufficient or too many nutrients or as a result of faulty digestion or utilisation of foods.

Anthropometric indices are commonly used in order to classify individuals as malnourished or of normal nutritional status. The extent of child malnutrition in a population is often

described in terms of current prevalence of stunting, wasting, underweight, and overweight and obesity. Children who have a height for age Z-score (HAZ) of -2 or lower are assessed as stunted, children who have a weight for height Z-score (WHZ) of -2 or lower are wasted and children who have a weight for age Z-score (WAZ) of -2 or lower are categorised as underweight. Obesity and overweight are defined using body mass index: children with a BMI Z-score of 2 to 3 are assessed as overweight and children with a BMI Z-score of 3 and higher as obese.

Malnutrition can also be clinically defined according to signs such as muscle wasting, loss of subcutaneous fat, hanging gluteal skin and "old man's face". There are three major clinical syndromes of clinical severe childhood malnutrition including marasmus, kwashiorkor and marasmic kwashiorkor. Marasmus is defined as a non-oedematous form whereas kwashiorkor and marasmic kwashiorkor are identified by oedema (figures 1 and 2). Marasmic kwashiorkor is a mixed form of marasmus and kwashiorkor characterised by presence of both wasting and pitting oedema.

Figure 2 Signs of marasmus
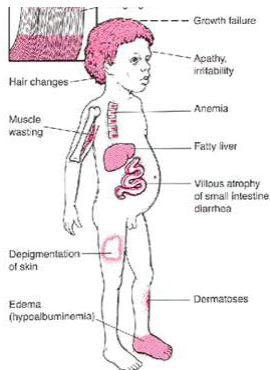
Figure 1 Signs of kwashiorkor

In marasmus, wasting of muscle and of subcutaneous tissues is the most striking pathological abnormality and the marasmic child therefore appears very thin [3]. Oedema is not noticeable. Children with extensive marasmus are characterised by a relatively large head, "old man's face" and shrunken buttocks. Although deficit in height is a feature of the disease, wasting is more pronounced than stunting. The skin is typically dry with patchy hypopigmentation and scaling [4]. In marasmus there is reduced hair growth [5]. There are also combinations of signs including dyspigmentation, decurling and thin hair [6]. Dermatosis as seen in kwashiorkor is absent in children with marasmus. Similarly, a fatty liver is rarely found.

Oedema is the most significant and defining feature of kwashiorkor [3]. There are significant variations of oedema severity. It can come as an enlargement around the eyes, swelling of feet and hands and can occur as generalised oedema. Dermatosis is common on the extremities. Hair abnormalities are striking when the disease process is of a long duration. Abnormalities include straight hair, dyspigmentation and thin hair as in marasmus [6]. Fatty liver resulting in enlargement of the liver is also commonly reported as a feature of kwashiorkor [7, 8].

1.3 The global problem of malnutrition

Although child malnutrition is still among the most serious of global problems, children's nutritional status is improving. The prevalence of stunting is declining and according to UNICEF 40% (257 million) of the world's children in 1990 suffered from stunting whereas in 2013 the proportion had decreased to 25% (161 million) [9] (figures 3 and 4). The prevalence of underweight is also decreasing. In 1990 25% (160 million) were affected by underweight; in 2013 it had been reduced to 15% (99 million) (figures 5 and 6). There has also been a significant decline in wasting; from 19% (122 million) in 1990 to 8% (51 million) in 2013. While the prevalence of stunting, underweight and wasting is being reduced the prevalence of overweight and obesity is increasing. Globally 5% (32 million) of children were overweight in 1990 and in 2013, 6% (42 million) were overweight.
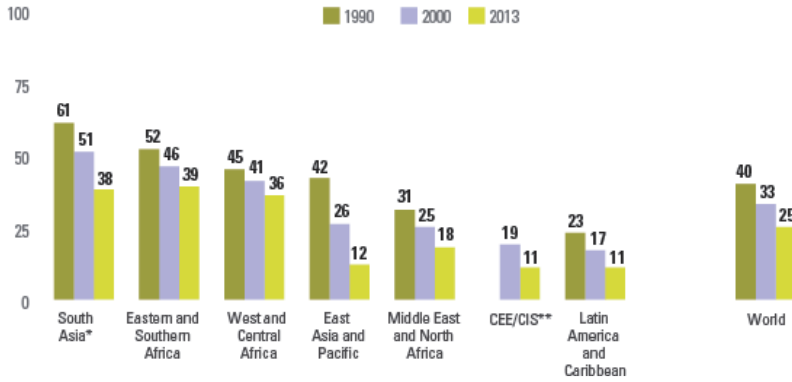
Figure 3 Percentage of children under 5 who are stunted, by region, 1990 to 2013

** CEE/CIS Central and Eastern Europe and the Commonwealth of Independent States
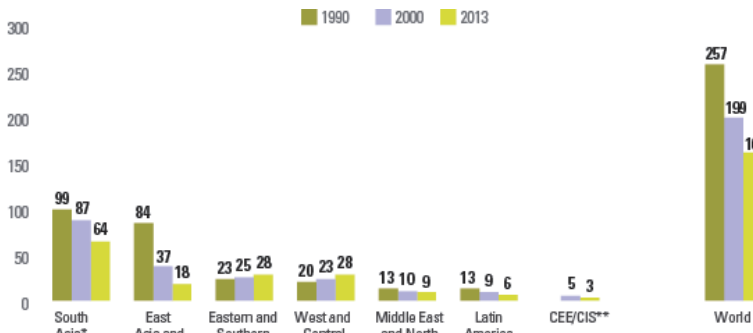
Figure 4 Number in millions of children under 5 who are stunted, by region, 1990 to 2013
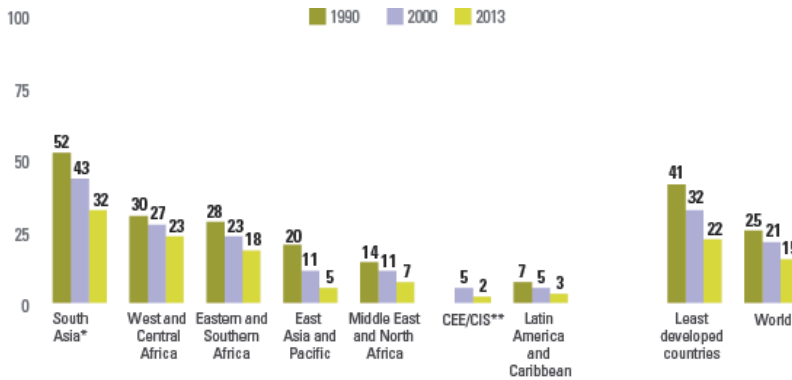
Figure 5 Percentage of children under 5 who are underweight, by region, 1990 to 2013
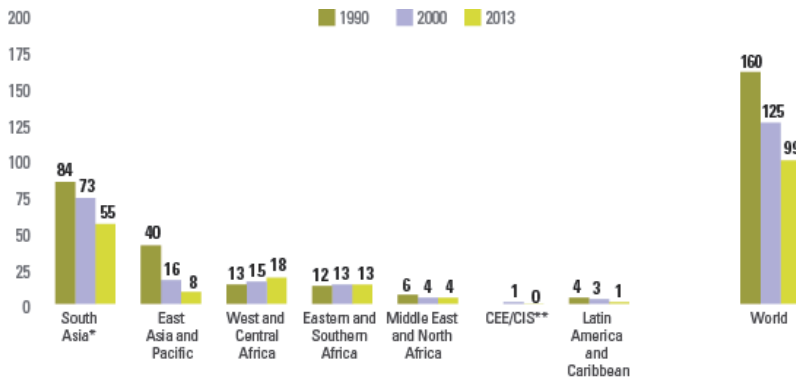
Figure 6 Number in millions of children under 5 who are underweight, by region, 1990 to 2013

1.4 Micro-nutrient deficiencies

In many regions micro-nutrient deficiency is a problem, particularly iron, vitamin A and zinc deficiency. Globally, 18.1% children below the age of five were affected by anaemia and 1.5% by severe anaemia in 2011[10]. Commonly, clinical assessment of signs of xerophthalmia, night blindness, and serum concentration of retinol is used to estimate the prevalence of vitamin A deficiency [10]. The prevalence of night blindness in pre-school children in 2011 was 0.9% and 33.3% children had a serum concentration of retinol that was lower than 0·70 μmol/L [10]. There are insufficient data to determine zinc deficiencies in sub-populations. Using national food availability and dietary requirements, a study from 2012 estimated that 17% of the world's population had an insufficient zinc intake [11].

1.5 The burden of marasmus and kwashiorkor

There are few surveys that provide data on the prevalence of marasmus and kwashiorkor. Given that marasmus is characterised by extreme wasting, children with marasmus are commonly assessed by a WHZ-score of -3 or lower. The global prevalence of children with severe wasting was 3% in 2011 and, with a prevalence of 5.6%, Central Africa was the region with the highest percentage of children suffering from severe wasting. [10]. At present little attention is paid to kwashiorkor and more recent surveys that report the prevalence of kwashiorkor at a country level are scarce [12].

The condition of kwashiorkor is transitional and typically those who suffer from the disease recover after a few weeks or die from the disease [13]. This makes it difficult to capture the magnitude of kwashiorkor in cross-sectional surveys that report prevalence of malnutrition. Nevertheless the disease is still an important health problem in rural areas where children consume a diet low in dietary diversity, often consisting of two major staples. Correspondence from 2008 in *The Lancet* reported that from 25 000 to 32 000 Malawian children were treated for kwashiorkor every year [14]. An older survey of about 25 000 Malawian children aged between one and three years carried out in 1994 reported the prevalence of kwashiorkor to be 2.5% [15].

There is some evidence that the occurrence of kwashiorkor and marasmus is declining. A retrospective study in Nigeria compared the number of children who had been hospitalised with kwashiorkor, marasmus, measles, and gastroenteritis between 1983 and 1991,with those from 1993 to 2001 [16]. It found that the number of kwashiorkor cases dropped from 938 to 276 representing a decline of 70.6%.

1.6 Regional disparities in malnutrition

Some parts of the world have experienced a significant drop in the percentage and numbers of children with malnutrition [9]. According to UNICEF, Asia has experienced a significant decrease in malnutrition and the most pronounced decline occurred in the East Asia and Pacific region [9] (figures 3 and 4). In this region the prevalence of stunting reduced from 42% to 12% and underweight from 20 to 5% during the period from 1990 to 2013. There was also a notable decline in the percentage and number of children with stunting in South Asia, although this region still has the largest number of children with stunting in the world.

Sub-Saharan Africa experienced a more limited progress in reducing malnutrition. In Eastern and Southern Africa 52% of children suffered from stunting in 1990 and in 2013 prevalence had declined to 39%. In Western and Central Africa the percentage declined from 45% to 36%. As to underweight, there was a decline in Eastern and Southern Africa from 28% to 18% and in Western and Central Africa from 30% to 23%. The numbers of children who suffered stunting and underweight in sub-Saharan Africa increased during this period (figure

4). Whereas South-East Asia and the Pacific have been successful in reducing the proportion of children who suffered from wasting, South Asia has not [9].

Evidence points to the significance of economic growth in reducing the problem of malnutrition, and regional disparities in malnutrition can therefore be explained as a result of differences in socio-economic development [17]. Economic growth resulting in better income, food security and improved health services is a crucial pathway to better child nutrition [18], whereas poverty and inability to purchase enough quality food is closely related to the high prevalence of malnutrition.

While regions such as East Asia and Latin American and Caribbean (LAC) have been successful in reducing the number of people living in poverty, sub-Saharan Africa and South Asia have not. In 2015 these last two regions accounted for 80% of the global poor [19]. Three-fifths of the world's extreme poor live in five countries located in these regions including Bangladesh, India, China, the Democratic Republic of Congo, and Nigeria [19].

Asia and LAC benefitted significantly from the Green Revolution which brought about important improvements in agricultural productivity and output and was associated with poverty reduction [20, 21]. The revolution led to an increase in income and a reduction in food prices and thereby contributed to better nutrition [22]. The impact of the Green Revolution was modest in Africa and in 2013 30 out of 35 African countries produced less food per head of population than they did in the 1960s [20].

In spite of its economic growth, South Asia faces serious problems of poverty and has the second largest number of people living in severe poverty and the highest prevalence of wasting in the world [9]. The region's failure to reduce poverty and malnutrition has been related to growing social inequalities and its inability to promote food that addresses nutrition security [23].

1.7 Child malnutrition in the Democratic Republic of Congo

Child malnutrition constitutes a serious threat to child survival and development in the DRC. The Demographic and Health Survey (DHS) from 2013/14 provides data on the prevalence of malnutrition in children below five years in 2013 in the DRC. According to the survey, 43% of the children suffered from stunting, 8% from wasting and 23% from underweight

[24]. Comparing the DRC DHS 2013/14 data on prevalence of malnutrition with global figures and figures from sub-Saharan countries, the DRC had the highest proportion of children suffering from stunting (table 1). The percentage of underweight children was significantly higher than globally, higher than eastern/southern Africa and equal to western/central Africa. The percentage of children with wasting was equal to the proportion of children suffering from wasting globally.

Table 1 Prevalence of children younger than 5 years with stunting, wasting, wasting and underweight globally, in sub-Saharan Africa and in the DRC 2013, expressed as percentages [24, 25]			
	Stunting	Wasting	Underweight
Global	25	8	15
East/southern Africa	39	7	18
West/central Africa	36	11	23
The DRC `	43	8	23

Table 2 shows that during the period from 2007 to 2013 the prevalence of all types of malnutrition dropped slightly in the DRC [26]. Both in 2007 and 2013 the prevalence of malnutrition was higher in rural than in urban areas and the largest gap was in stunting. In stunting and underweight the rural–urban gap increased in the period from 2007 to 2013. As to wasting, the gap between rural and urban areas was slightly reduced in this period. The DHS report from 2007 states that 4.1% of children had oedema. The Equatorial Province, where this study was undertaken, had 4.8% of children with oedema, making it one of the provinces with the highest prevalence of children with oedema: the Orientale Province had the highest prevalence. The DHS report from 2013/14 does not provide information about children with oedema.

Table 2 Prevalence of children younger than 5 years with stunting, wasting, and underweight 2007 to 2013 in the DRC as a whole, as urban or rural populations, and in the Equator province, expressed as Z-scores. [24, 25]						
	HAZ-3	HAZ-2	WHZ-3	WHZ-2	WAZ-3	WAZ-2
The DRC 2007	24.2	45.5	4.3	10.0	8.4	25.1
The DRC 2013	22.5	42.7	2.6	7.9	7.2	22.6
The DRC Urban 2007	17.5	36.7	4.9	10.3	6.5	18.9
The DRC Urban 2013	13.8	32.5	1.4	5.0	4.0	14.3
The DRC Rural 2007	28.7	51.5	3.9	9.9	9.7	29.3
The DRC Rural 2013	26.2	47.1	3.2	9.1	8.5	26.1
The DRC Equator 2007	29.5	50.9	5.7	10.1	14.3	29.2
The DRC Equator 2013	19.0	38.2	1.7	6.0	5.2	19.4

Food insecurity and high prevalence of child malnutrition in the DRC should be understood in the context of economic and political developments in the DRC. People are living in extreme poverty with little support from the state and since the 1970s there has been a breakdown of the formal relationship between the state and the people with the state being unable to provide essential social services [27]. Despite the DRCs wealth in natural resources, its population is among the poorest in the world, and because of its poor scores with regards to income, health and education it was, in 2014, ranked as second to last according to the Human Development Index [28]. As reported by the World Bank Poverty Strategy Paper from 2013, seven out of ten households lived below the poverty line of US $1.25 per capita per day with poverty being most rampant in rural areas and eight out of ten households in the rural areas classified as poor [29]. Many spend a large portion of their income on buying their own food and low income severely reduces their ability to purchase enough and adequate food. According to an International Food Policy Research Institute (IFPRI) report from 2014, 47% of the households in the DRC were food insecure. The proportion of food insecure households is particularly high in the rural areas and 54% of the rural population were food insecure [29]. In 2011 the DRC was the only country where the food situation in 2011 dropped from "alarming" to "extremely alarming," and the same year the country scored worst on the IFPRI Global Hunger Index [30-32]. Civil war and political instability has restricted the government's ability to stimulate socio-economic growth.

In rural DRC the majority of the population depend on small-scale agriculture. This sector is characterised by low productivity and during the last five decades the agricultural sector as a whole has deteriorated [31, 33]. The small-scale agricultural sector has faced a number of problems including the government's failure to invest in agricultural extension and infrastructure, shortage of technicians and mismanagement. [39]. In addition to restricted growth in the small-scale agricultural sector, other sectors such as the education and health sectors have declined in the past two decades [27, 34].

1.8 Consequences of child malnutrition

Child malnutrition has severe implications for child survival, child development and human capital. In the forms of foetal growth restriction, suboptimal breastfeeding, stunting, wasting, and vitamin A and zinc deficiency, malnutrition has been attributed to 45% or 3.1 million

child deaths [10]. South and Central Asia have the highest death rates, while south, central and western Africa have the largest proportion of children dying from malnutrition [1]. Marasmus and kwashiorkor have especially high mortality rates [35].

Malnutrition is a risk factor for poor child development. Poor child nutrition is associated with a decline in physical activity and apathy in children [36, 37]. It has been related to a reduced exploration of the environment in terms of looking at and touching objects [37, 38]. Undernutrition has a number of long-term consequences and negative implications for human capital in terms of school achievement, economic productivity and mental health. Undernutrition can cause damage to the brain and thereby affect cognitive and educational development [39, 40]. Child malnutrition has been associated with failure of school enrolment at due time [41]. It can have implications for school achievement, and stunting at an early age has been found to be a predictor of poor cognitive performance and achieved school grades [41, 42]. Linear growth relates to employment and growth restrictions at two years have been reported to reduce the likelihood of employment in formal sector jobs [43]. Nutrition is a predictor of income, and improved nutrition during childhood has been associated with better earnings [44]. Growth failure during early childhood may have implications for an adults' mental health and has been related to depression and increased suicidal ideation [45-47].

1.9 Determinants of child malnutrion – the conceptual framework on the causes of malnutrition

Determinants of malnutrition are commonly described as tiers of interrelations and several models have been developed to illustrate these relations. The models typically build on the UNICEF conceptual framework that distinguishes between three levels of determinants; immediate, intermediate and basic level [48-51]. This framework links the problem of child malnutrition at local levels to factors at higher levels and in this manner malnutrition is viewed as a larger development problem [52]. The model presented in *The Lancet* series on maternal and child malnutrition 2008 builds on this and distinguishes between three levels of causes: immediate, underlying and basic [1] (Figure 7).
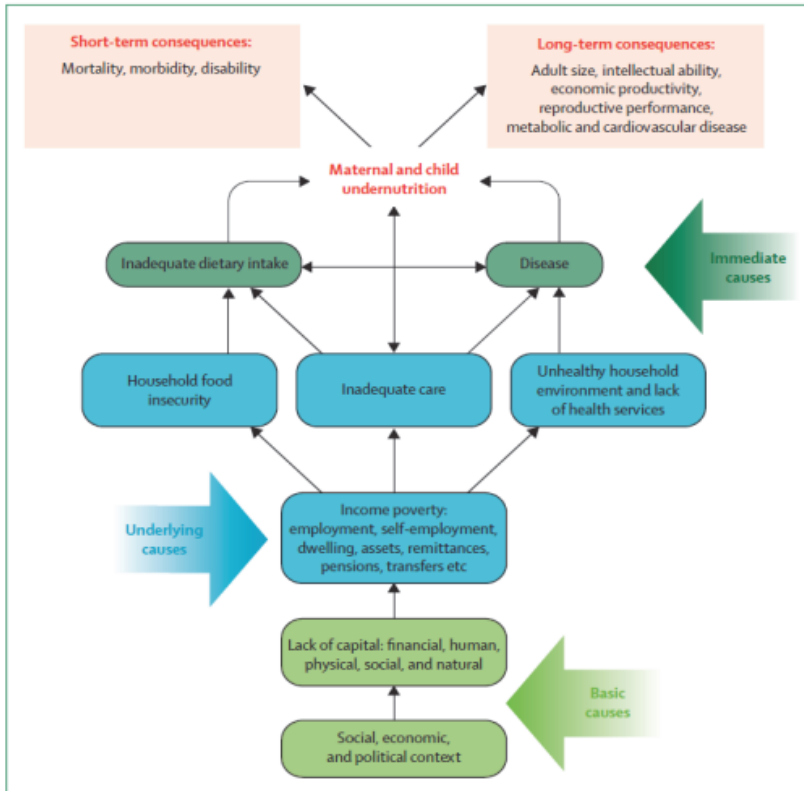
Figure 7 Framework of the relationships between poverty, food insecurity and other underlying causes to maternal and child undernutrition and their short-term and long term consequences [1]

Immediate causes manifest themselves at the level of the individual and comprise dietary intake and disease as interlinked. The immediate causes are influenced by underlying causes which manifest themselves at the household level. The framework recognises food insecurity, inadequate care for mothers and children and unhealthy environment as causes at this level. Poverty is considered a key determinant with implications for all underlying factors [50]. The underlying factors are influenced by basic causes of malnutrition and the model recognises access to human and natural capital, and the social, political and economic context as basic causes.

The conceptual framework provides a general representation of the relationships between a set of variables and nutritional outcomes. It is used to guide the direction that research can take and factors in nutrition to be examined. Determinants on malnutrition have mostly been

investigated in quantitative research and various statistical models have been applied to capture the chain of causations. Statistical models have been used to examine determinants at one level or at multi-levels that investigate a large number of variables at different levels that influence nutrition [50, 53, 54].

The following sections deal with selected causes of child nutrition with particular relevance for the determinants addressed in this thesis. At the immediate level, the thesis deals with the relationship between diet and nutrition and examines dietary determinants of marasmus and kwashiorkor. Hence this introduction provides an account of literature on this theme. At the underlying level, food security is a major topic and this thesis highlights social aspects of household food production and consumption. An overview of the literature on the links between social organisation of food production, food security and nutrition is provided. Given that poverty is regarded as a major underlying cause of malnutrition, research findings on the relationship between poverty and social inequalities in nutrition are presented. Data used in the thesis were collected in a rural area and research on the rural–urban gap in malnutrition and factors that can explain these differences are accounted for. In terms of basic causes, child malnutrition in the DRC should be understood in the context of the economic, social and political development of the country. The introduction therefore provides examples of how researchers have explained malnutrition as a result of processes at the macro level. Finally the introduction demonstrates how the conceptual framework can be used as a tool for developing strategies to reduce child malnutrition.

1.10 Diet and malnutrition

Diet is considered as an immediate determinant of nutritionals status. The term is commonly defined as the food that a person eats every day. There are two major ways of describing a diet [55]. It can be portrayed with regards to chemical composition which is typically described in terms of nutrient content, or it can be described as food and food groups. An account of diet as specific compounds or groups of compounds allows for making direct links to human biology. Epidemiological studies that contain measurements of total nutrient intake provide data that can be used to test hypotheses on how intake of a specific nutrient is associated with the risk of developing a disease. The use of food items to represent a diet also provides useful information that can underpin epidemiological studies. Data on food and

food groups can be used to investigate how consumption of certain foods or food groups relates to the risk of developing a disease. The association of food and food groups with certain health outcomes can be used to hypothesise about the relationship between specific compounds and health outcomes. The relationship between different food items is complex and reciprocal and it can therefore be problematic to use food items to represent a diet. [55]. As an attempt to solve this issue researchers have grouped food items into food categories. Scholars have used this approach to investigate how a diet determines different health outcomes. The approach has also been applied in the study of how dietary diversity influences child nutritional outcomes and other child health outcomes.

In order to achieve optimal growth and development a child needs to be fed regularly with energy-rich and nutrient-dense food. Monotony in a diet is characteristic of a poor diet. [56]. A monotonous diet is typical for poor communities in low-income countries with a high prevalence of child malnutrition [56]. In such communities cereals, roots and tubers are often the only sources of energy, proteins and micro-nutrients, also for young children [57-59]. Complementary food in many sub-Saharan countries consists of gruel and porridge based on such staples [60]. Besides having a low nutrient density these diets have poor organoleptic qualities that further suppress appetite [56].

There is strong evidence that children who consume a diverse diet will meet their nutrient needs whereas children who consume a monotonous diet face problems meeting their needs. Based on simple counts of food and food groups consumed, researchers have developed indicators to measure dietary diversity [61, 62] and hence to provide estimates of the adequacy of diets. Applying this approach, studies have shown that dietary diversity is positively associated with better intake of energy and multiple nutrients. For example, a study from Mali showed that counts of food groups consumed by children can predict dietary adequacy [63]. There is a link between low dietary diversity and malnutrition and a study based on 11 Demographic and Health Surveys demonstrated that low dietary diversity was associated with stunting either as a main effect or in interaction with other factors [64]. Low dietary diversity is also related to wasting and undernutrition [65].

1.11 Diet and marasmus and kwashiorkor

There are three major theories of the causes of marasmus and kwashiorkor: the protein-energy, the free radicals and the gut microbiota hypotheses. These three hypotheses relate the development of these forms of malnutrition to diet. The following sections present the three hypotheses.

The protein-energy hypothesis

The development of marasmus and kwashiorkor has been linked to differences in diet and metabolism, and earlier these two forms were termed protein-energy malnutrition. The term was used because marasmus was thought to be caused by energy deficiencies, whereas kwashiorkor was considered a result of protein deficiency [66]. Marasmus was understood as a response to starvation and shortage of energy leading to wasting of muscle and subcutaneous fat. This development was considered a physiological adaptive process: as energy is unavailable from food, energy is made available from the body. Through wasting, important body processes are protected. Muscle protein is broken down and amino acids become available which are important for the synthesis of glucose. In particular, in the early phases of energy deficiency, glucose is crucial for brain metabolism. Children with marasmus are characterised by an absence of metabolic abnormalities and they are able to maintain homeostasis even during long periods of little or no food [66]. This is because through the process of wasting, important amino acids and other compounds crucial for homeostasis become available. This hypothesis was supported by findings showing that children with marasmus have normal levels of serum albumin [67]. Furthermore the concentration of lipoprotein is upheld in marasmus and a fatty liver does not therefore develop in marasmus [68].

According to the protein-energy hypothesis, children who develop kwashiorkor, unlike marasmic children, fail to maintain homeostasis. Kwashiorkor was seen as a result of children consuming a diet high in energy but low in protein. It was suggested that this consumption pattern led to pathological abnormalities such as a fatty liver and oedema. A shortage of dietary protein means that the amount of amino acids required for essential synthesis is inadequate. In consequence, serum amino acid composition is altered with the liver albumin pools being distorted. This distortion has two consequences. First, less β-

lipoprotein is synthesised and thereby less fat is transported from the liver and the liver is enlarged. Second, less plasma albumin is synthesised causing the development of oedema. Several studies relate hypoalbuminemia with kwashiorkor and the development of oedema [69, 70]. Findings from a study that described the prevalence of marasmus during the Ethiopian famine 1983–1985 were considered to support the theory of kwashiorkor pathogenesis [71]. Kwashiorkor was present in those areas with diets deficient in protein while kwashiorkor was not found among pastoralist consuming a diet sufficient in protein.

The protein-energy hypothesis has been challenged. A longitudinal study comparing the diet of Indian children with marasmus and kwashiorkor, did not find any differences in the intake of energy and protein in children with marasmus and kwashiorkor [72]. A study of twelve hospitalised children with kwashiorkor or marasmic-kwashiorkor, showed that there were no changes in plasma albumin levels before and after loss of oedema in kwashiorkor [73]. The study therefore questions the causal association of hypoalbuminemia and oedema in kwashiorkor. It has also been reported that children with kwashiorkor can lose their oedema on a diet low in protein [74].

The free radical hypothesis

Golden and Ramdath postulate that oedema in kwashiorkor is caused by an excess of free radicals [75]. Free radicals are atoms or molecules containing unpaired electrons. Damage results from the free radical encountering another molecule and seeks to find another electron to pair with its unpaired electron. In healthy persons, free radicals are produced in relatively small quantities during respiration. According the free radical hypothesis, kwashiorkor is a result of flux of free radicals caused by different noxae with the body defending itself against invading mechanisms by producing free radicals. In line with this, kwashiorkor is triggered by an infection. Kwashiorkor also typically occurs in areas of low-income countries where there is unsafe food handling and storage and, during periods of food insufficiency, food is being spoilt. In these areas weaning foods are also heavily contaminated [76]. Additionally, protective pathways are compromised in kwashiorkor. These pathways typically require micro-nutrients and in kwashiorkor there are probably deficiencies in these micro-nutrients causing a loss of the protective pathways. Consequently the damage and the disposal of toxins in the free radical action cannot be balanced out. In kwashiorkor the lack of antioxidant capacity causes pathological abnormalities including oedema, fatty liver, skin

lesions and hair discoloration. Golden and Ramdath suggest that the levels of micro-nutrients are low because of degeneracy caused by radicals and inadequate dietary intake. Blood concentration of glutathione is the principal intracellular de-toxicant. Studies have also found that blood concentration of glutathione is higher in marasmus than in kwashiorkor [77]. As a result of low glutathione concentration children with kwashiorkor, unlike children with marasmus, lack the mechanism to eliminate the increase in free radical damage.

There are some limitations to the free radicals theory's ability to explain kwashiorkor. An earlier clinical study of children with kwashiorkor and marasmus that examined their antioxidant status concluded that it was uncertain whether differences in antioxidant status are the cause or consequence of kwashiorkor [78]. The free radical hypothesis eliminates the argument that there is a relationship between kwashiorkor and low protein or amino acid intake and emphasises that low levels of glutathione in kwashiorkor are caused by oxidation. On the other hand a clinical study showed that by supplementing children with kwashiorkor with cysteine they increased their glutathione concentration and suggested that a low glutathione concentration could be related to insufficient intake of amino acids [79]. Linking free radical production to oedema is also problematic. As an example, AIDS is associated with increased oxidative stress, but not with oedema [80].

The free radical hypothesis has also been challenged in several population studies. For example, a randomised controlled trial of children aged 1–4 years, assessed the efficiency of antioxidant supplementation in preventing kwashiorkor [81]. The intervention arm received antioxidant powder containing riboflavin, vitamin E, selenium and N-acetylcysteine, while the control arm received a placebo of an identical looking powder. The study failed to show that the supplementation of antioxidant powder prevented children from developing kwashiorkor.

The microbiota hypothesis

Abnormal gut microbiota may be a contributing factor to severe acute malnutrition and the hypothesis has been tested in population and animal studies [82]. These studies have found important differences in the microbiota in well-nourished children over time, while children with kwashiorkor had a delay in maturation of microbiota [83-87]. The studies suggest that there is a link between the consumption of a nutrient-poor diet, abnormal microbiota and the development of severe malnutrition. The results of these studies should be considered as

preliminary [35]. They have compared kwashiorkor children with well-nourished children but not with marasmic children. In the animal experiments there was no presence of oedema and the experiments cannot be considered as kwashiorkor experiments.

1.12 Food and nutrition security

1.12.1 Household food security

Household food security is recognised as an underlying determinant with implications for diet and children's nutritional status [88]. In 1996, the World Food Summit agreed that food security exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for a healthy and active life.

There are several pathways to household food security. In most studies income is described as the principle determinant of household food security and a household's access to food is related to household income relative to food prices. The link between income and food security is strongest in urban areas because most urban dwellers need to purchase their food and depend on a cash income for this purpose. Income-related food security is also about household behaviour and prices of other goods and services demanded by the household [88].

Determinants of food security in rural areas where people are dependent on small-scale farming differ from those in urban areas. In rural areas people tend to be less dependent on cash income and among small-scale farmers food consumed is often from their own production while the market is a secondary source of food [89]. In consequence, there is a close link between agricultural production and food security. Production has a direct impact on food security since access to food is determined by a household's ability to produce enough adequate food for its needs. Indirectly, food production can generate an income that can be used for purchasing food or used for services that have consequences for nutrition.

Globally, small-scale farming is an important livelihood and plays a dominant role in rural areas of low-income countries. Small-scale farming is commonly defined as farms smaller

than two hectares and according to FAO 2014 there were 400 million small-scale farms globally of less than one hectare and 75 million of between one and two hectares [90]. According to data from 2004 the overwhelming majority of small-scale farms are located in Asia, while Africa has the second largest number of small-scale farmers [91]. In terms of small farms in Africa of less than one hectare, small-scale farming is most prolific in Egypt, Malawi, and the DRC [90, 92]. Poverty and child malnutrition is common among small-scale famers [92, 93]. In areas where small-scale farming is the predominant livelihood, there are typically few or no alternatives to agriculture [94].

Household characteristics

Among small-scale farmers the household is typically responsible for agricultural production and there is therefore a close link between household organisation, food production and nutrition [95, 96]. The literature describes the household as a functional unit that constitutes a resource-holding unit and forms a production and consumption unit [96]. Household size is a factor that impacts food security. Studies have found that larger farm households are more food insecure than small households and researchers have argued that this is because larger households have a higher burden of people to feed [97-99]. Nevertheless, large family size can positively influence food security because it generates a labour supply [89]. Accordingly there is a close link between food security and a household's access to labour; households with sufficient labour are less likely to be food insecure [97, 100]. As an example, an earlier study concluded that large extended families are effective for practicing shifting agricultural cultivation while nuclear family households are more appropriate for intensive agriculture [96, 101]. In the same way, it is argued that, in an environment where resources are widely dispersed, larger household units are more effective than smaller units [102]. Household demographic composition and dependency ratio, that is the number of consumers divided by the number of producers, influence the unit's ability to produce sufficient food. An increase in the ratio is supposed to result in an increase in the burden of the productive population to maintain food production [103-105].

The manner in which agricultural activities can be accomplished is also linked to the way production is organised including division of labour along gender lines [96]. In traditional agriculture, division of labour tends to be based on gender, and studies report that men typically contribute to the most physically-demanding activities such as felling trees, clearing

land and ploughing, whereas women hold the major responsibilities for planting, weeding, harvesting and food processing [106-109]. A skewed gender composition may therefore lead to the household failing to accomplish its task and have negative impacts on food security.

The gender of the household head matters and it has been reported that male-headed farm households are more likely to be food secure than female-headed households. [89, 105, 110-113]. Female-headed households are often disadvantaged as to access to land, livestock, extension services credit, education and markets [114, 115]. Diseases and especially HIV/AIDS have had severe impact on food security and HIV/AIDS has different consequences for different types of households [116]. HIV-affected households are more food insecure than those not affected by the disease and the affected households are typically female-headed households that have a high dependency ratio and experience labour shortage [112, 117].

Inter-household cooperation

Effective food production may also depend on the existence of other forms of food production units in addition to the household unit [96]. Africa has a long tradition of breaking bottlenecks in agriculture by organising communal labour in the form of reciprocal work groups. In some areas, work groups still play an important role. In the context of urbanisation, work groups have been a tool to overcome labour shortages resulting from people moving from rural to urban areas [118].

The literature distinguishes between two types of communal groups; work groups and festivity groups [119, 120]. Work groups are based on reciprocal exchanges of labour. They are mobilised during different phases of production and are typically employed to solve agricultural tasks that a household unit cannot solve alone [121]. In this manner agricultural activities such as clearing land, planting and weeding can be completed at the optimal time. Those who refuse to take part in work groups will not receive assistance from groups when they are in need of such support.

Work groups are typically reciprocal work groups made up of households that work in rotation on each other's fields during different phases of food production [111, 119, 121]. The groups are egalitarian groups and membership is based on kinship, neighbourhood and friendship. Commonly the groups have a leader, but the work is directed by the host. Most

groups are male groups but there are also female groups [118]. In order to mobilise work groups some type of reward is required and this often includes everyday food and alcoholic drinks [122]. Food provided is not considered as payment for the work that is undertaken and the event is not regarded a festive occasion.

In contrast to work groups, festive groups are not based on reciprocity and the groups do not have a fixed membership. Similarly to work group, mobilisation of festive groups involves preparation of food and drinks, but when this is consumed the group activities are completed and the groups dissolve. Typically it is a person with access to sufficient capital to provide the necessary refreshment and entertainment who is in a position to call a festive work group [119].

Rural households that participate in farmer groups and other forms of community organisation have been found to be more food secure than those who do not [105, 111]. It is argued that households that take part in community organisation can benefit in a number of ways from such cooperation including improved management of resources, better marketing of farm products and facilitation of technology transfer.

Land tenure

The social aspect of food security and nutrition incorporates the concept of land tenure. Tenure is a social concept that defines relationships between individuals and groups and it concerns an individual's rights and obligations [123, 124]. These rights can derive from customary and statuary law or the institution of marriage and control of inheritance. There is a strong link between land tenure and food security and access to land is among the most important factors determining household or individual food security, especially in areas prone to famine [125]. Considering land and food in a linear causal relationship, it starts with access to land resources and continues with production, income generation and access to food. Tenure security has important consequences for food production and access to food, and with greater security farmers might be more confident that they will benefit from improving their land and greater tenure can increase the chances of accessing credit [125]. Registration of land rights is considered a factor that improves tenure security, but in many sub-Saharan countries land is still under a customary land tenure system and land is usually

not registered [125]. Furthermore, severe food crises in situations that allow for alienation of land, for example through sale, can lead to a permanent loss of livelihood [123].

Other drivers of household food security

Besides the social organisation of households there are several other drivers of small-scale farmers' food security. Low adoption of new technologies, dysfunctional input and output markets and limited access to agricultural extension are factors associated with food insecurity [126-128]. In addition, environmental factors have implications for food security and in many areas declining soil fertility resulting in low yields poses a threat to food security [129]. Climate change causing drought and water scarcity further worsen the situation for small-scale farmers [127, 130]

1.12.2 Individual food security

Although a household may appear to be food secure this does not necessarily mean that all household members have access to enough adequate food. Inequalities in food allocation are usually a result of some household members being favoured while others are being discriminated against. In some societies discrimination is based on gender and may contribute to differences in nutritional status between boys and girls. Several studies have reported discrimination against girls in South Asia [131-133]. Preferential treatment of boys can be related to the low status placed on women in parts of the region [133, 134]. In some settings girls are expected to be less active, consume less food and are consequently fed less food [135]. Staple food may also be allocated differently from more nutritious food with girls being denied nutritious food [134]

Whereas findings from Asia have shown that malnutrition is more common among girls than boys, research from sub-Saharan Africa on gender differences in food allocation and nutritional status is inconclusive. Some studies from this region have shown the prevalence of stunting and underweight to be higher in boys [136-138]. These differences have been explained as a result of discrimination against boys in food allocation. Researchers have suggested that girls are favored because of the important role of women in sub-Saharan African agriculture [139]. Other studies from the region, however, have found higher energy intakes among boys than girls and that more girls are malnourished than boys [139].

Besides gender, studies have found preferences in food allocation based on age. In some societies, children below the age of five are favoured in intra-household food allocation [140, 141]. Contrary to this, other studies have found consumption of especially nutritious food to be skewed towards men while children and especially young children were disfavoured in food allocations and that food was unequally distributed to secure food supplies for the working men [142].

Transitory food insecurity and seasonal variations in child malnutrition

The literature distinguishes between transitory and permanent food insecurity [88]. Transitory food insecurity describes seasonal food insecurity, while permanent food insecurity describes long-term food insecurity. Subsistence farmers typically face food insecurity in the period before the harvest of food crops. Studies have therefore accentuated the close linkage between agricultural seasons and nutritional stress. For example, a study using data from a Zimbabwean clinic-based growth monitoring programme found that prevalence of underweight peaked during periods of food shortage prior to the harvest [143].

1.13 Socio-econonomic determinants of malnutrition and inequalities in nutrition

At the underlying level, poverty is considered a key determinant with consequences for all underlying determinants of malnutrition. Children's nutritional status is closely linked to the quality and quantity of food consumed. These conditions may in turn relate to people's socio-economic positions and ability to purchase sufficient and adequate food. The literature has paid attention to how socio-economic conditions determine nutritional outcomes and social inequalities in nutrition. Studies have documented income-related social differences in nutrition and they have found the highest prevalence of malnutrition in the poorest segments of the population [144-147]. Social inequalities have been found in all LMIC countries that have so far been studied [146, 148]. There are regional differences in terms of inequality in malnutrition and the largest have been found in the Latin America and Caribbean region [146].

Research from Ghana reports that the odds for developing malnutrition were four times higher among children living in the poorest households than among children living in the

richest households [145]. Given that children's nutritional status is determined by the household's socio-economic position, improvements in income levels are associated with a drop in the probability of children being malnourished [144, 149]. In growing economies, benefits of development tend to favour the richest and inequalities therefore widen in emerging economies [144]. However the relationship between poverty and malnutrition is not absolutely clear. As an example, a study from Mexico found that poverty was not a necessary condition for malnutrition [150]. The study found that children's nutritional status was related to factors such as father's occupation as farmer, job stability, presence of family network and size of network.

Besides income-related social inequalities several other social factors have implications for children's nutritional status and education: maternal education especially has been identified as a key factor influencing nutrition [145]. Better education can lead to increased awareness of the significance of healthy behaviour, good sanitation practices and the importance of favouring children in household resource sharing [50, 145, 151]. Still, a study from Ghana found that maternal education only had a small effect on nutrition [144]. It was suggested that this was because a large majority of women in Ghana only have primary or no education. Furthermore, inequalities in access to safe drinking water, hygienic toilet facilities and health services have been found to create inequalities in nutrition [144, 145, 152]. Malnourished children have been found to live in households that have no access to safe drinking water or hygienic toilet facilities [144]. In addition, long travel times to health facilities have been be found to be negatively associated with children's nutritional status [152].

Growing inequalities in nutrition are particularly evident in expanding economies in low income countries. Economies in sub-Saharan Africa and South Asia have experienced economic growth and a reduction in employment rates, yet these countries have not managed to reduce the problems of poverty and malnutrition [23, 149, 153]. Employment rates have typically improved for the rich but only to a limited extent for the poor. The poor are often engaged in the informal sector, a sector characterised by seasonality of employment and limited adherence to minimum wages. Agrarian crises have also contributed to increasing social inequalities [23, 154]. Such crises are one of the factors that have resulted in a move from rural to urban areas where the middle class has typically been able to improve their economic status while the poor have not [23].

The relationship between poverty and nutrition manifests itself in a number of ways. Cost has been shown to be a major factor that influences food choices and to be a barrier to the intake of nutritious food among low-income consumers [155-157]. A healthier diet tends to be more expensive than an unhealthy diet and, among the poor, healthy food can be unaffordable [157]. In these countries people spend about half of their income on food with the poor spending a higher proportion than the better-off on food [23, 158]. Fluctuations in food prices therefore have severe consequences, especially for the poor and may change the profile of their food expenditure. This is because there is a strong relationship between prices of quality and food expenditure. As prices for nutrient-dense food increase people spend less of their income on quality food [23, 159, 160].

1.14 The rural–urban gap in malnutrition

There is a body of evidence that in LMIC countries rural children are at a higher risk of malnutrition than their urban counterparts [161-164]. Research that used 2005 DHS data from 15 sub-Saharan countries found the prevalence of stunting to be higher in rural than in urban areas in all the countries examined with an overall odds ratio of 1.7 [161]. Furthermore, using DHS data from 36 countries in South Asia, sub-Saharan Africa (SSA), and Latin American and the Caribbean (LAC), a study reported that the nutritional status of urban children in all sample countries was better that the nutritional status of children living in rural areas. Greatest differences were found in LAC countries with stunting rates being more than double in rural areas than those in urban areas [163].

Since there is a close link between poverty and nutrition, higher poverty rates in rural areas may explain rural–urban differences in nutritional status [163, 165]. In low-income countries, poverty remains mainly a rural problem and in 2014 the majority of poor people lived in rural areas [166]. Sub-Saharan Africa and South Asia in particular face severe problems of rural poverty. Globally there has been a rapid decline in poverty in rural areas with the decline related mainly to poverty reduction in East Asia. In contrast, sub-Saharan Africa and South Asia have witnessed a slight increase in rural poverty. In 1988 the rural share of poverty in sub-Saharan Africa was 72% while in 2008 it was 75% and in South Asia it was 80% in 1988 and 86% in 2008 (figure 8) [2] .
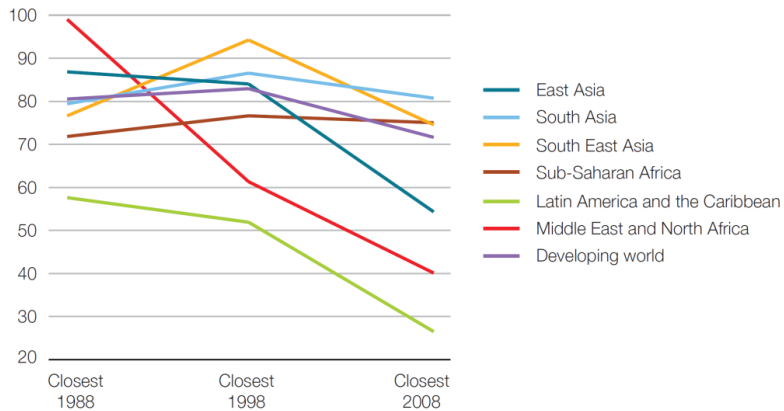
Figure 8 The rural share of poverty as a percentage of those living on less than US $1.25/day[2]

Rural poverty can be associated with a stagnating small-scale agricultural sector in many countries. The rural livelihood in low-income countries is not diverse and small-scale farming including crop production, livestock keeping and artisanal fishing is the dominant livelihood. The small-scale agricultural sector has been constrained by factors such as limited public support and declining finances for agricultural research and extension, falling real prices for many agricultural commodities, the impact of HIV/AIDS, environmental degradation and climate change [92].

The rural–urban gap in nutrition can also be explained as a result of differences in maternal education and access to health services [163]. Women in rural areas tend to have limited access to prenatal and postnatal birth care and breastfeeding, while complementary feeding practices are poorer and preventive health-seeking behaviours are less common in rural than in urban areas [163, 167].

In general, urbanisation plays a positive role in reducing the number of people living in poverty, but urbanisation has also increased the urban share of poverty. South Asia and sub-Saharan Africa have the highest proportion of the urban population living below the poverty line [168, 169]. As cities grow, more and more people live in the outlying parts of the cities and many of these have developed into slums. In such areas, poverty is caused by a lack of income opportunities, insecure living conditions and short supply of municipal services. As a result of increases in urban poverty, the burden of malnutrition is, in many countries,

gradually shifting from rural to urban areas, and the prevalence of child malnutrition is rising among the urban poor [161, 163]. In this manner the rural–urban gap in nutrition is declining in countries experiencing rapid urbanisation.

1.15 Malnutrition and macro economic, political and social processes

At the basic level the determinants of nutrition include the potential resources that are available to a local community or to a country, access to technology and the quality of human resources. The utilisation of resources and how these resources are transformed into food and nutrition security are again influenced by national and international economic and international factors. Political, economic, cultural, and social factors affect the use of these potential resources and how they are translated into resources for food security, care, and health environments and services [50]. Basic factors are considered as being of particular importance for child nutrition because factors at the immediate and the underlying levels can be very vulnerable to changes within or between basic causes. This relates to basic factors such as climate, trade, the rate and pattern of economic growth, food and energy prices and land-use policies [170].

A few studies have examined determinants of malnutrition from historical perspectives. A study from Ghana links malnutrition to broader historical, political and ecological factors [145]. Malnourished children were more likely to live in the disadvantageous northern regions and the regional inequalities resulted from historical developments and geographical conditions. During the colonial period, the northern regions became labour reserves for the mines in the southern part of Ghana. The northern parts of Ghana are characterised by low rainfall, savannah vegetation and periods of severe drought. An ethnographic account of severe child malnutrition among the ethnic group Chagga of northern Tanzania also links the problem of malnutrition to socio-economic change [171, 172]. During pre-colonial times the better-off Chagga households distributed food to poorer households during crises. In the area, there was no child malnutrition in times of enough of food. When the study was carried out in 1970 to 1975 and 1989, there was less sharing of food between households, and among poorer households child malnutrition had become common. In spite of the Chagga community being a relatively wealthy society the incidence of child malnutrition was high. Malnutrition was associated with several factors including history of colonialism and

commercialisation of agriculture which made the society more vulnerable to global economic fluctuation trends. During the post-colonial period the society had experienced a breakdown in the traditional system of redistribution of food. In addition, the increasing problem of landlessness caused by population growth made the poorer population more susceptible to food shortages.

Economic growth and political conflicts in particular are known to have a significant effect on nutrition. Using data from 116 countries a study found that economic growth had a positive impact on nutrition and that a 10% increase in per capita GDP led to a 1.7% decline in stunting prevalence over a period of five years [173]. Economic growth was found to reduce stunting by facilitating access to sanitation, better education for women and increased access to food in terms of quantity and quality [173]. Researchers argue that economic growth is likely to have a significant positive impact on nutrition if political choices are made to reduce inequality [174]

A study from Uttar Pradesh in India dealt with conflict and nutrition and reports that political violence had important negative effects on child nutrition especially through a reduction of the ability of households to cope with drought [175]. An eight-month ceasefire period reversed the adverse effects of drought on undernutrition in communities previously affected by conflict.

Research has investigated links between governance and nutrition and found that good governance in terms of dimensions such as bureaucratic effectiveness, law and order, political stability and restraint of corruption plays a role in reducing malnutrition [173]. A report that examined governance in the nutrition sector in six LMIC countries [176] found that presidential involvement, agenda setting by bringing to attention nutrition policy as a national concern and strengthening inter-sectoral cooperation were key factors in the governments' advance in efforts to reduce child malnutrition.

2. Rationale and objectives

2.1 Rationale

Child malnutrition in the form of stunting, wasting, underweight and micro-nutrient deficiencies is a major global health problem and contributes to a large proportion of child deaths [10]. Thousands of children in low-income countries suffer from marasmus and kwashiorkor, both forms of severe malnutrition [14, 15]. Mortality is especially high among children with severe malnutrition [177-179]. The DRC has one of the highest proportions of children suffering from malnutrition in the world and while globally there has been a significant decrease in the prevalence of malnutrition the decline has been slow in the DRC [10, 24, 26]. In low-income countries malnutrition is more widespread in rural than in urban areas. This rural–urban gap is in many low-income countries diminishing, but in the DRC it is increasing [24, 26, 161, 163]. Rural people typically depend on small-scale subsistence farming, and food insecurity and child malnutrition is very common among small-scale farmers [92, 93]. The dominant livelihood in the rural parts of the DRC is also subsistence agriculture [180]. Consequently, there is a pressing need to understand why children living in rural areas where people depend on producing food for their own consumption are at high risk of malnutrition. This thesis contributes to the literature on child malnutrition by integrating the various determinants of child malnutrition and demonstrating how, in a specific rural local setting, the interaction between the determinants has implications for children's nutritional status.

Understanding seasonal, age and gender determinants of malnutrition is important for the timing and targeting of nutritional interventions. Studies have demonstrated variations in malnutrition associated with agricultural season as well as being linked to increased morbidity during the rainy season [143, 181, 182]. Literature on the link between seasons and different forms of child malnutrition is limited. Children, especially toddlers and young children, living in a food insecure environment are at high risk of malnutrition. There are relatively few studies that describe the timing of different forms of growth faltering in children and most studies describe growth faltering associated with height for age [183-185]. In households that appear to be food insecure individual members may not receive enough

adequate food and research has described gender discrimination in food allocation and gender differences in nutritional status. The literature on gender inequalities in food allocation and nutritional status in sub-Saharan Africa is inconclusive [136-138, 186].

In rural areas in low-income countries the diet is generally monotonous and bulky and cereals tubers and roots account for most of the protein and energy intake [187]. In this environment children are at high risk of malnutrition including severe malnutrition in the forms of marasmus and kwashiorkor. Over several decades researchers have examined dietary factors in marasmus and kwashiorkor via cohorts, case control studies and randomised control trials [72, 188, 189]. These investigations have so far failed to find any differences in diet between children who develop kwashiorkor and those who do not, they have also failed to find differences in diet between children who develop kwashiorkor and those who develop marasmus [35, 189]. There is therefore a need to further investigate dietary factors in kwashiorkor.

Food insecurity and child malnutrition is still widespread in poor rural areas where people rely on small-scale farming. Among small-scale farmers the household is typically responsible for food production and consumption and the organisation of the household impacts the household's ability to sustain itself [90, 96]. Food insecurity and malnutrition is also a result of factors beyond the household level and malnutrition in the DRC has been closely related to distal factors such as the state's failure to deliver social services [54, 190]. In order to understand the relationships between social organisation of food production and nutritional outcomes, there is a need to explore interlinkages between child nutrition, household organisation, the local social setting and factors related to macro socio-economic conditions. Models have been developed to illustrate the relationship between determinants of malnutrition at different tiers, and guided by these models researchers have, mostly using quantitative data, investigated how nutrition is associated with a wide range of variables. This literature does not present theoretical tools that can be applied for a multi-level analysis using qualitative data in the analysis of socio-economic factors influencing nutritional outcomes.

2.2 General objective

To generate knowledge about seasonal, demographic, dietary and socio-economic factors determining moderate and severe child malnutrition in Bwamanda, a rural area of the DRC.

2.3 Specific objectives

To investigate longitudinal occurrence patterns and the course of malnutrition among pre-schoolers and to compare these patterns among clinically and anthropometrically defined malnutrition (Paper I)

To describe the season-, gender -, and age-dependent incidence of moderate clinical malnutrition, marasmus and kwashiorkor, and compare these with rates obtained using anthropometrical definitions of malnutrition (Paper I)

To investigate associations between diet and the development of kwashiorkor (Paper II)

To compare the causal influence of dietary risk factors for kwashiorkor with those of marasmus (Paper II)

To describe the social context of food production and nutrition (Paper III)

To explore how some households succeed in ensuring that their children are well-nourished while others do not (Paper III)

3. Material and methods

3.1 The Democratic Republic of Congo

Figure 9 Map of the Democratic Republic of Congo, provinces and location of Bwamanda

History

The Democratic Republic of Congo (DRC) is a former Belgian republic (figure 9). Colonial rule in the Congo began in the late 19th century and in 1885 King Leopold II of Belgium created his own personal colony, the Congo Free State. The state was characterised by its violence against and exploitation of the indigenous population. In 1908 the Belgium government took control over the country and named it the Belgian Congo. The country achieved its independence in 1960. After a long period of civil war Joseph-Desire Mobutu took power in 1965 and renamed the country Zaire. The president maintained his power by using state resources to reward his supporters and this policy became colloquially known as 'de brouillez-vous' ('help yourself') [27]. The policy resulted in a strong deterioration of the

country's economy and infrastructure [180]. In 1997 armed forces forced Mobuto to flee and the same year Laurent-Désiré Kabila, took over the power and named the country the Democratic Republic of Congo (the DRC). President Kabila was assassinated in 2001 and was succeeded by his son Joseph Kabila. An election was held in 2006 in which Joseph Kabila won and the same year he was sworn in as president. Kabila was re-elected in 2011. Since 1997 and up to now the political situation in the DRC has been characterised by civil wars and corruption. The problems stem from the genocide in Rwanda in 1994 resulting in the civil war in the DRC. The armed groups that were responsible for the deaths of ethnic Tutsis and Hutus fled across the border into the DRC. The death toll of the civil war, 1998–2004, has been estimated to be 3.9 million [191]. In 2013 the UN secured an agreement with the militia groups in the eastern provinces to end the conflict.

It is in this historical context that underdevelopment in the DRC should be understood. Major constraints on developments include poor governance, uneven distribution of services and infrastructure and long-lasting conflicts especially in the eastern part of the country.

Food production and food insecurity

Limited economic and social development has led to a situation characterised by food insecurity and malnutrition in many parts of the DRC. At independence the country was self-sufficient in food but since independence there has been a decline in the country's capacity to produce food [31].This decline can be related to mismanagement and the government's failure to invest in agricultural extension and infrastructure. Although the agricultural sector makes up the livelihood of 70% of the people, only a very small proportion of the country's government's expenditure is spent on agriculture and, with an expenditure of about 2.5% of the national budget, the DRC spends much less on agriculture than other countries in the sub-Saharan region [192]. Due to limited private and public investment in agriculture, small-scale farmers face a number of problems. They lack access to quality planting material, fertiliser, pesticides, improve techniques and new information. Agricultural development, which is also severely constrained by poor infrastructure, roads and waterways connecting local communities, agricultural land and markets, has been described as "in an advanced stage of deterioration" [192].

Health services

There is a significant lack of public health services in the DRC and in some parts of the country the public health system has totally collapsed [34]. Government service provision is insufficient and access to healthcare professionals is limited, particularly in rural regions, where the poorest live [193]. People's access to health services has further deteriorated as a consequence of the existence of a system of non-regulated fees for health services [34]. Since colonial times, missionary organisations have played a significant role as service providers. These organisations are still important and fill a gap in public health service provision. In addition, the informal health service providers play an increasingly important role.

In 2013 the per capita expenditure on health in the DRC was US $26 and the country spent 3.6% of its GDP on health while on average SSA countries spent 5.7% [194] . The government has responded to weaknesses in the health system by increasing the share of the national budget allocated to the health ministries, and from 2012 to 2014 this share increased from 6.1% to 8.9% [193].

The education sector

Due to increased funding by the government and international donors the educational sector did show some improvements in the period from 2001 to 2010 [29]. The enrolment rate at the primary school level improved and there was an increase in attendance rates at the secondary level, but the completion rate at this level declined [29]. Overall, 80% of children aged 6–11 years attended primary school in 2013 and attendance was better in boys (82%) than in girls (79%) and better in urban (87%) than in rural areas (77%) [24]. The quality of primary education provided is considered low and only one third of children residing in urban areas and one fifth of those in rural areas reach fifth grade [195]. Several factors have contributed to the poor quality of primary education in the DRC including few trained teachers, unsatisfactory and insufficient teaching materials and inappropriate teaching and learning environments. Illiteracy rates are relatively high and among people aged 6 years or older, 19% of women and 8% men have no education [24]. The school attendance rate at secondary level was 43% in 2013, with 59% of the children in the urban areas attending and

34% in the rural areas, with the figures for boys and girls being 49% and 37%, respectively. Factors such as early marriage and pregnancy disfavoured girls' access to education.

Access to clean drinking water and sanitation

The government has paid limited attention to the utility service sector. Very few people have access to safe drinking water and in 2010 74% of the population had no access to safe drinking water [29]. In comparison with other sub-Saharan countries the use of sanitary services is low. In 2013, 21% in urban areas and 17% in rural areas used such services [24], whereas the average for Sub-Saharan countries was 44% and 24%, respectively [29].

Economic development

In spite of its wealth in natural resources the majority of the citizens live in poverty and in terms of GDP per capita based on purchasing power parity (PPP), the DRC with a PPP of US $809 was, in 2013, ranked as the fourth poorest country in the world [196]. Since 2010 the country has experienced economic growth and with a growth rate of 8.7% in 2104 the country had a growth rate which was significantly higher than the average for sub-Saharan countries [197]. The mining sector is growing fast and is one of the main drivers of the DRC's economic growth. There are also indications that the country will improve its human development index position [198]. Still, the pace and quality of the economic growth is considered to be insufficient to significantly reduce poverty in the country [199].

3.2 Equatorial Province

The Equatorial Province, where this study was undertaken, is situated in the north-west part of the DRC, in the Congo River Basin. The province covers an area of 403 292 km², 17% of the DRC and with a population of about 5.8 million it is sparsely populated [200, 201]. The Mongo is the dominant ethnic group while groups of Sudanese origin dominate the northern parts. Mbandaka is the capital city and the province is further divided into three districts, namely; North-Ubangi (district capital Gbadolite), South-Ubangi (district capital Gemena), and Tshuapa (district capital Boende).

The major livelihood includes small-scale agriculture, hunting and fishing. Equatorial province holds unexploited deposits of iron ore. The province was the home area of

President Mobutu Sese Seko and during his reign it received significant governmental support. According to a UNDP report from 2009 as much as 94% of the population lived below the poverty line of 1.25 US dollars a day and the province was thereby the poorest in the country [200].The proportion of children suffering from malnutrition in 2013 was high: 57% of the children under five years of age were stunted and 7.6% wasted [202].

3.3 The Bwamanda area

The research was carried out in the South Ubangi District in the Equatorial province [203-205]. The area, known as Bwamanda, is located at 19.2 degrees east and 3.2 degrees north. Bwamanda features savannah land and patches of forest along the rivers. The villages are located on the savannah or near the borders of forests. The area is relatively good for farming. The climate is tropical and although no month is completely dry, there are pronounced dry and wet seasons. The rainy season lasts from April to November and the dry season from December to April. Rainfall is estimated in the range of 1400–2000 mm/year.

Bwamanda village and its surrounding villages form the Bwamanda area, with a total population of about 209,000. Bwamanda is a large village that has grown into a centre with a marketplace, a hospital and associated health centres. The Bwamanda hospital operates as a first referral hospital for the health district/zone of Bwamanda. Currently, the local NGO, Centre de Développement Intégral Bwamanda (CDI-Bwamanda) is responsible for providing social services in the area.

3.4 The Ngbaka

The following paragraphs describe aspects of the social life of the Ngbaka ethnic groups focusing on aspects related to food production and nutrition. The account is primarily based on data collected for the contemporary household study (see below).

The Ngbaka is the major ethnic group settled in Bwamanda constituting about 98% of the population [203]. They originated from the area around Lake Chad and came to central Africa in the early 19th century and settled in different parts of North and South Ubangi districts [203].

The Ngbaka live in villages whose names typically begin with the pre-fix *bo* which means descendant, followed by the name of the founder of the village. Each village has a chief (capita) who is supported by several assistants. Land administration is a major task of the village leadership with the leaders negotiating in land conflicts and being responsible for land redistribution. In Bwamanda, land is under a traditional community-based property system and individual farmers are entitled to usufruct rights. In accordance with the Ngbaka patrilineal descent system, land rights are transferred from father to son. In order to uphold usufruct to land the family is required to continuously cultivate it and reside in the village.

Agriculture

The Ngbaka residing in Bwamanda are predominantly subsistence farmers and differ from many of the neighbouring ethnic groups that originally were gatherers and hunters. They produce their staple foods through shifting cultivation. Maize and cassava are the major staples, while soybeans and groundnuts are cash crops. Some farmers also grow crops such as taro, sweet potatoes, pigeon peas, beans and various vegetables and fruits. Farming techniques are very traditional; all operations are done by hand, farmers do not have access to draught animals and fertilisers are unavailable. Farmers combine the use of traditional planting material and new varieties including varieties of maize and cassava provided by the NGO CDI-Bwamanda. Agricultural fields are cleared during the first two months of the year, planted and weeded in April up to the beginning of June. The first harvesting of maize takes place in June and the other in November, while farmers begin to harvest cassava in October. After three to four years the soil is exhausted and land is left fallow for several years. Fallow land is sometimes used for oil palms and tree crops. Normally fields are located one hour away from the homestead but the fields can also be located up to 4 hours walk from the homesteads. To supplement crop production, poorer farmers keep poultry and guinea pigs while better-off farmers raise pigs, sheep, goats and cattle.

Gathering, fishing and hunting

In addition to agriculture the Ngbaka gather wild food, fish and hunt. Men hunt whereas women gather wild food, but both men and women fish. While men fish using rods, nets and traps, women catch fish in temporarily dammed pools as they drain out. Natural resources in Bwamanda are widely dispersed. In the dry season people go on foot for several hours to fish in the rivers. Men hunt small game in the neighbouring forests.

Labour organisation and inter-household cooperation

Agricultural work is carried out by the household members and has a gender-based division of labour. Men are responsible for clearing land and women do most of the work during weeding and harvesting. In addition men produce a range of crafts including mats and baskets. Households also mobilise labour and capital through the traditional Ngbaka work group, an inter-household cooperation called *gbisa*. These are reciprocal groups consisting of close kin and neighbours that are mobilised to solve tasks that the household unit have difficulties solving alone such as land clearing and timely weeding. There are male as well as female *gbisa*, with the male work group being engaged for clearing land and the female work group for weeding. During *gbisa* the host serves *ka* (see below) and cassava leaves and farmers who can afford it serve meat, fish and palm wine.

Gbisa and capital accumulation

Other than being a vehicle for labour mobilisation, male *gbisa* is also organised to facilitate capital accumulation and investment, especially in livestock. In the first year, the person who initiated the group receives an agreed upon number of sacks of groundnuts from group members, and in the following years others obtain sacks of groundnuts on a consecutive basis. Capital from groundnut *gbisa* is typically invested in livestock, bicycles and sewing machines. There is also a second form of gbisa for capital accumulation whereby the group establish a revolving fund that provides cash in a sequential manner to its members.

Food consumption

Typically the Ngbaka serve two meals per day. Usually the main meal consists of *ka*, a stiff porridge made from cassava and maize flour. The porridge is served with a stew made of cassava leaves occasionally strengthened with fish and groundnuts. If there are any left-overs these are consumed for breakfast the next day. In between meals people drink tea, palm wine and eat various fruits. Infants are predominantly breastfed up to the age of three months, at which point food is introduced to complement breast milk. Normally breastfeeding continues up to three years. Early complementary food consists of a gruel basically made from *ka* and cassava-leaf stew. For the meals water is collected from deep tube wells or from streams in the forests. During meals household members are served the same food, but split into groups; women and young children in one group, older children in another and men in the third.

Rites of passage and marriage

The Ngbaka still organise traditional circumcision ceremonies for boys and girls. As a part of this rite the children are isolated in the forests for several days. After the rites are completed girls can marry and many girls still marry at very young ages. In pre-colonial times the Ngbaka were not polygamous, but with the introduction of a cash economy polygamy became more common. The Ngbaka practice endogamy and prefer to marry within their own group. Marriage is either arranged as a formal agreement between the parents and involves payment of bride-wealth mostly in kind. Since many would like to avoid the expensive bride wealth elopement weddings are common. The Ngbaka are patrilineal and practice patrilocality, with the wife moving to her husband's father's household after marriage.

The household

The villages are located along the main roads, but poorer households tend to reside in the outskirts of the village or in the fields. Wife and husband live in a rectangular house whereas a round house is used for storing grain and it is commonly used as a sleeping place for children. Usually women prepare the meals on a three stone fire outside the houses, but during the cold season indoor cooking is done in the round hut. Wood is also burned during the night for heating. In the compound there are typically a number of fruits trees including papaya and bananas.

There are great variations in household organisation and this study illustrates how households vary in size and composition. There are large multi-generation households and households that are large partly as a result of influx of children from households that have ceased to exist. Other households are large due to polygamy. Small households comprise nuclear families where the sons have broken away from their family and established their own households. Local people use wealth to differentiate between households and distinguish three categories – relatively wealthy, average and poor. The relatively wealthy cultivate a variety of cash crops including palm oil and many have become wealthy through *gbisa*. The averagely wealthy are able to produce enough food for their household members during normal years, while the poor are not. The poor are also characterised by their limited capacity to participate in *gbisa* as a result of not being capable of providing the food required to host a *gbisa* and of being considered unable by other farmers.

3.5 Service provision in Bwamanda

This description of service provision is primarily based on information collected during the field work carried out in relation to the contemporary household study (see below). In 1967 individuals from the Order of Capuchin Friars, an order of friars in the Roman Catholic Church, established a local integrated development organisation, CDI-Bwamanda (Centre de Développement Intégral Bwamanda) and located the organisation's headquarters in Bwamanda village. This village has grown into a small centre that now has a large market place. It hosts a hospital associated with peripheral health centres situated in the surrounding areas of Bwamanda. In 1989 there were 10 health centres covering 52 villages and in 2014 there were 16 centres covering 83 villages [206]. Services provided by the NGO include health care, access to safe drinking water and agricultural support. Currently the organisation runs the Bwamanda hospital and associated health centres. In order to improve access to drinking water the NGO has developed a number of deep borehole wells. CDI-Bwamanda has made several efforts to stimulate agricultural growth and provided farmers with improved planting material including early maturing maize and cassava, facilitated transport of maize for sale in Kinshasa and promoted coffee as a cash crop. A tsetse control program has permitted cattle raising, which was difficult earlier due to trypanosomiasis (sleeping sickness).

Since 1989/1991, when the longitudinal study was undertaken, there have been few political and economic changes in Bwamanda. The socio-economic development in the area has been constrained by several factors including restricted public service support and only minor private sector growth. Major assistance in the form of technical support and financial support, has come from the Belgian government and EU, but UNICEF and the World Bank has also provided support. International funds for development activities are provided through CDI-Bwamanda. Due to a decline in financial assistance from international donors over recent years, the organisation has had to scale down its operation and now concentrates on health services. In spite of this, CDI-Bwamanda health services are inadequate because of a shortage of qualified staff, basic equipment and essential medicine including ready-to-use therapeutic food to treat child malnutrition. A few years back the hospital received funding for developing local therapeutic food, but funding for this project has ceased.

3.6 Mixed method design

This thesis uses a mixed method design as described in figure 10. It is based on a quantitative historical longitudinal study from 1989/91 and a contemporary qualitative household case study from 2012/3. The data for the two studies were collected in Bwamanda, north-west DRC. Both provide information on factors associated with nutritional outcomes but they pursue two different methodological approaches. The longitudinal study is a dynamic population-based study that makes use of quantitative data on diet, children's nutritional status and health outcomes. The household study was informed by the outcomes of the longitudinal study and the need to understand the results of the quantitative study in local and macro-socio-economic settings. It uses qualitative household data and provides information on the Ngbaka socio-economic setting, food production, household organisation, inter-household cooperation and service provision.
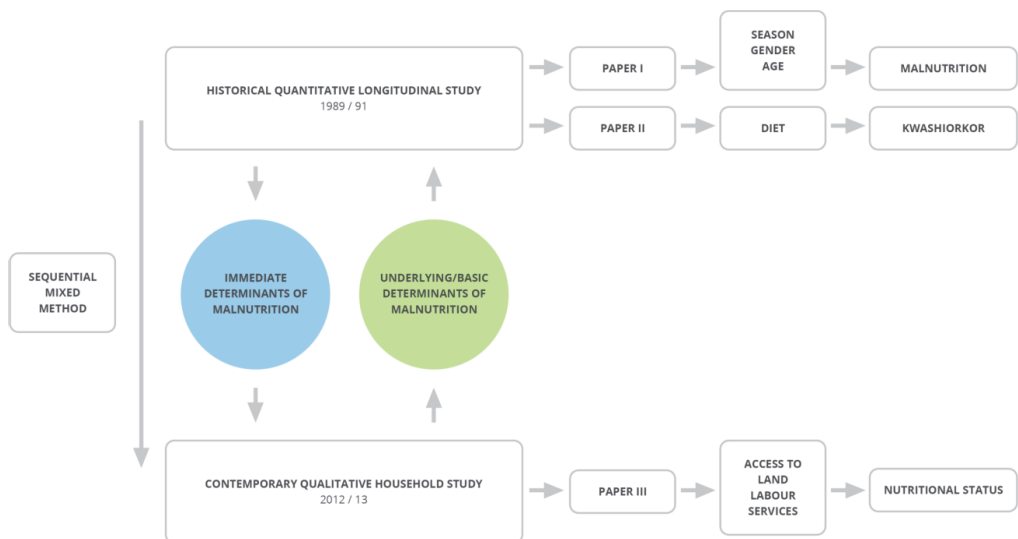
Figure 10 Mixed method design of the study

This thesis begins with a quantitative longitudinal study followed by a qualitative household case study. It therefore applies a mixed method design that makes use of both quantitative and qualitative approaches in a single research project to gather and analyse data [207, 208]. The literature distinguishes between different mixed method designs including a parallel form in which two types of data are collected concurrently and a sequential form in which one type of data provides the basis for the collection of another type of data [209]. This

thesis applies a sequential mixed method design as the contemporary household case study builds on results from the longitudinal study [210]. The two studies are stand-alone studies in the sense that results from the longitudinal study are presented in two papers and results from the household case study in another. The studies are integrated in the thesis only and not in the papers.

The intention of this thesis is to describe determinants of malnutrition as the interaction between factors at different tiers. The quantitative data allow for an analysis of a set of variables. The longitudinal study uses nutritional assessment and a questionnaire approach to create quantitative evidence of the relationship between nutritional status and a set of variables including the relationships between season, gender and age and malnutrition (paper I). The data are used to investigate determinants with direct implications for children's nutritional status and to examine the relationship between diet and the development of kwashiorkor (paper II).

There are several advantages of mixing methods. The qualitative data are used to identify determinants that form the socio-economic context of malnutrition and this allows for a further examination of the underlying and basic determinants of nutrition (Paper III). The thesis points at the importance of analysing child malnutrition as a result of a complex chain of causation that involves factors located at different tiers. The quantitative data mainly allow for an analysis of causation at one level and the data are analysed to identify immediate causes of malnutrition in terms of dietary determinants of kwashiorkor. The longitudinal study contains little information about underlying determinants of malnutrition such as household food security. The qualitative household study complements the longitudinal study and qualitative household case data are analysed in order to understand links between the social organisation of household food production and nutritional outcomes. Qualitative data are also used to explore basic determinants of malnutrition. Data that describe how the households are linked to other social entities with implications for nutritional outcomes were obtained and in this manner it is possible to explore how factors beyond the local setting influence nutrition.

3.7 The quantitative longitudinal study

The longitudinal study uses data that were originally collected to investigate mortality among children in Bwamanda [206]. The University of Leuven, Belgium took the initiative to implement the study. The study was part of a project entitled: "Maternal Determinants of Child Health and Care in a Rural Tropical Area".[206]. The objective of the study was to investigate maternal factors acting upon nutrition status, morbidity and mortality. The Flemish Inter-University Council and the Belgian Administration for Development Cooperation financed the project at the initial stage, while at a later stage Nutrica Research Foundation provided project funding. Data were collected between October 1989 and March 1991.

Data collection was undertaken by 15 field assistants holding a secondary school certificate. These had been trained at the Bwamanda hospital in simple physical examination, basic nutrition, nutritional assessment and conducting questionnaire interviews. As part of the training the assistants took part in a pre-survey. The assistants undertook 55 observations in total and inter-observation was supervised by a medical doctor. The exercise involved five children and the results of the assessment showed that for normal nutritional status the concordance was 91%, for mild nutrition 82% and for severe malnutrition without oedema 100%. During data collection these assistants were supervised by the senior researcher and his qualified colleague.

The size of the sample for the study was based on an estimation of how many child deaths are required to investigate child mortality in a multivariate analysis. It was projected that about 300 child deaths would be required and thus ca. 4000 children would have to be followed in a cohort stretching over a period of four years to obtain the proposed number.

At the time of the study the Bwamanda area consisted of 52 villages. Following a random selection procedure, 16 villages were selected for data collection. Later a preliminary census of the 16 villages was undertaken. Data collection was done during six quarterly survey rounds. At the first round there were 4328 children enrolled and when the study was completed a total of 5567 children had been included. During each survey round new children were entered while other children were lost as result of death or emigration. Children that reached the age of six years were excluded from study. Table 3 details the number of children at the different survey rounds.

Table 3 Number of children per survey rounds in longitudinal study						
Round	**Period**	**Previous total**	**Newly enrolled**	**Loss due to**		**Total**
				Death	Emigration	
1	1 October − 3 December 1989	0	4 238	0	0	4 238
2	1 January to 30 march 1990	4 238	271	21	37	4 451
3	1 April to 30 June 1990	4 451	328	22	42	4 725
4	1 July to 30 September	4 725	293	18	50	4 950
5	1 October to 30 December	4 950	337	67	53	5 167
6	1 January to February 1991	5 167	157	42	95	4 656

The survey included interviews, clinical examinations and assessments of the children's nutritional status. The interviews and the clinical examination of the children were carried out at a location in the village specially designated for this, although children who could not come to this location were examined during home visits. A pilot study identified the food typically consumed by children. In addition to standard clinical data on interval morbidity, information about mortality was collected.

Children's nutritional status was assessed through clinical and anthropometric assessment. Presence of wasting of the gluteus muscle, wasting at inspection and/or palpation without signs of marasmus or kwashiorkor were used to identify moderate clinical malnutrition (McM). Marasmus was assessed by inspection of abnormal visibility of skeletal structures and by absence or near-absence of palpable gluteus muscle without presence of oedema. Kwashiorkor was identified using the presence of pitting oedema of the ankles and/or feet as a criterion. To evaluate inter-observations in the clinical assessment of malnutrition, clinical staging was carried out. Malnutrition was classified into three stages: stage one with muscle wasting and/or palpation; stage two with muscle wasting including signs such as loss of subcutaneous fat, abnormally visible skeletal structures and "old man's face; and stage three, muscle wasting with pitting oedema. A child with no signs of these stages was assessed as normal.

The age of the children was determined by using the birth dates documented on the 'road to health charts' or parents' identity papers. Information on age was obtained in this manner for

90% of the children. For the remaining children age was determined through interviews using local events calendars.

An anthropometric assessment of nutrition and growth was conducted. Two anthropometrists measured weight and length/height. Length was measured using a measuring board. To measure the standing height of children older than 24 months a "microtoise" was used. Spring scales were used to weigh the children. Mid upper arm circumferences and skinfold thickness were also measured.

On the basis of this study a non-quantitative 24-hr. recall that included the 41 locally most consumed food items was developed (annex 1). The food questions were included in the questionnaire and interviewees provided "yes or no" answers to the questions if children had consumed the listed food items during the previous day. The interviewees were also asked about the number of meals prepared for the families and special meals prepared for the children and breastfeeding.

3.8 The contemporary household case study

The data for the household study were collected during three field work periods. In October 2012 an initial field visit was organised when Bwamanda hospital, health centres and several villages were visited. The major field work was conducted in February and March 2013 and during this period household case study data were collected. During a visit in November 2013 additional information about sizes of agricultural plots and the agricultural cycle was obtained.

Data collection and translation were done with the assistance of a teacher of English and French from a secondary school in Bwamanda. Prior to data collection he was provided with three days training in conducting semi-structured interviews and organising group discussions.

The study participants were recruited on the basis of purposive sampling. The sampling was based on two criteria: (1) recent history of severe malnutrition and hospitalisation of a child in the household, and (2) absence of a recent history of malnutrition among children in the household. Nurses and physicians working at the Bwamanda hospital identified four cases of children under-five-years who had been hospitalised for, treated and later recovered from

marasmus and kwashiorkor. These four children lived in four different villages located 3 to 50 km away from the Bwamanda village. With the assistance from nurses at health centres, four households with children under six-years who had not suffered from malnutrition were also selected. During vaccination the health centres had conducted anthropometric assessment and the results had been registered on the children's health cards. The nurses used this information to identify children that had been assessed using normal weight for age charts and found not to be underweight. Eight households in five different villages which were eligible for inclusion in the study were thereby identified. These eight households comprised 12 girls and 17 boys below six years, 24 girls and 11 boys above six years and 24 adult women and 21 men.

Triangulation of data collection methods was applied to develop a comprehensive understanding of socio-economic factors influencing food production and nutrition in Bwamanda and to test the validity of information from different sources of information. Data collection involved four methods including participant observation, semi-structured interviews, focus group discussions and key informant interviews. A total of 36 informants participated in the household interviews, group discussions and key informant interviews (table 4).

Participant observation was used to systematically describe activities and events in Bwamanda. In this manner, observations were used to learn about the life of the Ngbaka in a natural context. The method was applied to map agricultural activities, teams involved in food production and the spatial organisation of the villages, and within households to understand household composition, organisation of food production and consumption. The method covered participation for short periods in the daily life of the eight households recruited for the household study, as well taking part in activities in the areas where the malnourished children and the well-nourished children lived including eating together with villagers, walking to the water sources and visiting farmers' fields and fishing sites. In the course of farm visits, plots with different crops were measured using a GPS.

The use of semi-structured interviews allowed for the inclusion of open-ended information about social factors influencing child nutrition and local ideas on conditions that influenced local food production and nutrition. This method was used for collecting data on the household cases which again were used as a basis for understanding the links between the

local social context and child nutrition. Semi-structured interviews were conducted with the fathers and mothers of the children as well as with other adult household members of all selected households (table 4). The interviews were guided by an interview guide specifically made for that purpose (Annex 2). Each interview took about one and a half hours.

Informants	Number of informants	Methods	Dates
Table 4 Number of informants, methods used and dates for interviews and discussions			
Informants from households with malnourished children	10	In-depth interviews Participant observation	February/ March 2013 November 2013
Informants from households with well- nourished children	10	In-depth interviews Participant observation	February/ March 2013 November 2013
Village leaders	5	Two focus group discussions In-depth interviews	February/ March 2013 November 2013
Bwamanda hospital and health centre staff	4	In-depth interviews	February/ March 2013 November 2013
Primary and secondary school teachers	3	In depth-interviews	November 2013
CDI Bwamanda representatives	4	In-depth interviews	November/February 2012 February/ March 2013 November 2013
Total number of informants	36		

Focus group discussions were organised to gather knowledge from people and to obtain general information about the Ngbaka way of life. Three group discussions were held with male and female leaders to gain a better understanding of the Ngbaka socio-economic organisation. Information about social differentiation was obtained and group participants categorised the local people in their village according to their wealth. Thereafter they defined the criteria for categorising local people into different wealth categories.

A number of key informant interviews were conducted with people who knew Bwamanda well. Interviews were conducted with local leaders including the village chief, village secretary, chief assistants and older respected women to gain an understanding of village organisation, village leadership and land tenure. During these interviews the results of the

group discussion were discussed. CDI-Bwamanda leaders and Capuchin leaders were also interviewed. Information about the history of CDI-Bwamanda and services provided by the organisation was obtained in this way.

There is hardly any public transport in Bwamanda and with no private vehicles for hire, lack of transport limits the possibility of conducting research. The team travelled by motorbike taxi to reach the villages and conduct interviews.

The observation, interviews and focus group discussions were all carried out in the Ngbaka language and translated by the interpreter. All interviews were tape recorded. After each interview the interpreter and myself went carefully through the tape-recorded interview. The interpreter translated each point raised in the interview orally into English and I took notes. The meaning and interpretation of the interview data were then extensively discussed. Field notes from observations and informal conversations were kept in addition to reflection notes from each day of the fieldwork. These served as guides for analysis.

3.9 Approaches towards the analysis of determinants of malnutrition

In order to investigate determinants of malnutrition this thesis adopts three different approaches, a descriptive, an analytical and an explorative approach (figure 11). Epidemiological research distinguishes between a descriptive and an analytical approach as the two major types of approaches. Paper I applies a descriptive and Paper II uses an analytical approach. These two papers make use of the quantitative longitudinal study. Paper III applies an explorative approach and makes use of the household case study data.
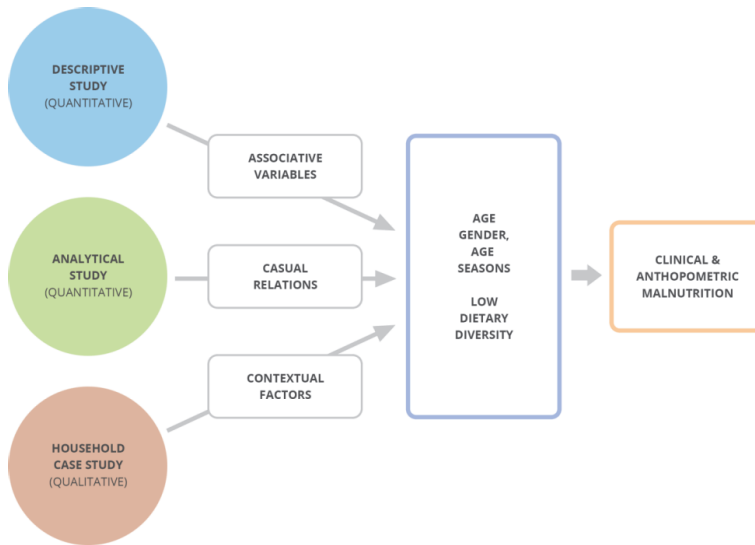
Figure 11 Methodical approaches pursued in the thesis

3.9.1 Descriptive approach (quantitative)

Descriptive epidemiological research concerns the frequency of a health outcome and how differences in frequency relate to dissimilar variables. In a descriptive study a health outcome is investigated without making inferences about the causal relationship between the phenomena and risk factors [211]. Such studies often examine the relationship between characteristics associated with the affected individuals and a health outcome. The studies may focus on personal characteristics such as age, gender and occupation. In addition descriptive research can demonstrate how geographical and seasonal factors relate to health outcomes. Descriptive studies apply different study designs including cross-sectional and ecological design.

In paper I a descriptive approach is used to investigate how the incidence of clinical malnutrition and anthropometric malnutrition is associated with season, gender and age. Clinical malnutrition was classified into three different categories; mild to moderate clinical malnutrition (McM), marasmus and kwashiorkor. The WHO-MGRS Child Growth Standards for the anthropometric scoring standards were applied to categorise the nutritional status as stunted, severely stunted, wasted and severely wasted [212]. An incident of

malnutrition was defined as malnutrition being present in a child during a survey round, but absent in the previous survey round.

An aim of the study is to examine how seasons relate to the occurrence of malnutrition. Following the usual seasons for the area and the agricultural cycle, the year was classified into (i) dry post-harvest (January–March); (ii) beginning of rainy pre-harvest (April–June); (iii) rainy (July–September); and (iv) end of rainy season post-harvest (October–December). In the analysis, occurrence rates of different forms of malnutrition during the dry and rainy seasons and pre and post-harvest periods were examined and age and gender differences in nutritional status for the four different seasons were compared.

3.9.2 Analytical approach (quantitative)

The aim of analytical epidemiological studies is to show the causal link between a set of determinants and health outcomes [211]. These studies investigate the effects of a set of risk factors on health outcomes. These relationships should be free from confounders. Analytical studies make use of experimental study designs including randomised control trials and observational studies including cohort, dynamic population and case control designs. A major purpose of a randomised control trial is to examine to what extent imposing an exposure alters the frequency of a health outcome whereas observational studies aim at examining to what extent an exposure causes a health outcome.

Paper II used a dynamic population study, the quantitative longitudinal study, and an analytical approach to investigate determinants of kwashiorkor and compare the causal inference of dietary risk factors for kwashiorkor with those of marasmus. A causal investigation method that used the whole study population as reference series was applied [213]. A smooth-in-time risk model containing all potential causal factors, including food items, special meals prepared for the child, breastfeeding, disease status, nutritional status, birth rank, age, season and number of meals was developed in order to understand factors that could cause kwashiorkor. The risk of developing kwashiorkor does not increase as children grown older. A non-linear variable that reflected the non-linear risk of developing kwashiorkor was therefore added as an independent variable.

3.9.3   Case study design and social field analysis (qualitiative)

Explorative approach and case study design

Paper III applies an explorative approach and a qualitative case study design. In contrast to the quantitative studies the paper makes use of open-ended information to uncover variables that influence nutrition. The case study approach is used to gain an in-depth understanding of a phenomenon, namely malnutrition, in its natural setting [214, 215].

The investigation is structured around the following research question; why do children living in certain households develop malnutrition while children in other households are well-nourished? The literature distinguishes between different types of case studies with a multi-case study design, as used in Paper III, being one of these [5, 6]. A multi-case study design allows for a comparison of different household cases in order to obtain an understanding of how various social factors have different implications for a household's food security and nutrition. In this manner the case study approach can be used to achieve a better comprehension of the relationship between the social setting and nutritional outcomes and to further explore underlying and basic determinants of malnutrition.

Social field theory

Social field theory, as developed by the French sociologist and anthropologist P. Bourdieu and the Norwegian social anthropologist R. Grønhaug, is used in the analysis of paper III. It is applied in the analysis of how determinants at the underlying and basic levels affect nutritional outcomes [216-218].

Social field theory stems from physics and field theory has been applied in a number of branches in science [219]. Field theory is considered a method for analysing causal relationships and building scientific constructs [220]. According to field theory, the properties of the totality, for example, in a physical field, are different from the structural properties of the parts of the dynamics. Furthermore, the structural properties are characterised by the relationship between the parts rather than the parts themselves and that a social event depends on the whole social field rather than some selected elements[220].

Social field theory conceptualises the society as a social space that is divided into a number of different fields. The fields are considered as small micro-cosmos or social entities that are

governed by their own rules that can be identified in terms of extension in social space, time, number of people and its distinctive characteristics [216, 217]. The social fields display structural implications in terms of the entities' effects on individual persons and the society as a whole [217]. Social field theory perceives the fields to be interconnected and the theory enables an analysis of how events at the local level are connected to processes at the macro level [217]. In the process of identifying social fields, the spatial aspect is particularly important [221, 222]. The question of a fields' boundaries cannot be explained *a priori* and a field can only be analysed through its effects and the boundaries of a field are observed where its effect ceases [220]. Fields are analytical units and are used in the mapping of people's preferences, actions and social practices. Field analysis is grounded in an approach that emphasises the importance of making use of data on social life and people's daily tasks in order to understand social organisation [216, 217, 222].

Social fields are related to different forms of capital and accumulation [223, 224]. The field has structured positions and the occupants have different resources and dispositions [225]. Accordingly, people's positions are anchored in the fields and fields are considered as arenas where people compete for the distribution of different types of capital including economic, political and cultural capital [225-227].

Social field theory has combined theories of generative process analysis as formulated by the social anthropologist F. Barth with theories about culture as, for example, developed in French structuralism and semiotics [222]. The theory therefore considers different social fields both as social organisations and separate fields associated with unique symbols and forms of communication [216, 217, 222].

Data analysis

Social field theory is used as a tool for analysing the data and as a method to identify social entities that have implications for nutritional outcomes. How location relates to food production and consumption was observed and discussed with key informants during the field work. This relationship was investigated with respect to smaller areas including the compound, the neighbourhood, the village and larger areas such as agricultural fields, natural areas in the vicinity of the villages and the Bwamanda area. In this manner separate bounded areas, termed social space, could be identified. Major characteristics of social activities were identified by describing the context of production and consumption. In terms of discovering

field characteristics the emphasis is placed on the way the Ngbaka organise food production activities. By making a linkage between social space and activities with their own characteristics, separate fields could be delineated. From the description of the household cases and field characteristics, a field's implication for nutrition is further singled out and by describing a field's effect, a better understanding of the field's specific property is achieved. The fields are considered as existing through their effects on households and the household cases were therefore useful in order to define field boundaries and where one field began and another field ceased. To understand how the fields have different implications for food security and nutritional status, cross-case comparisons and analyses were performed. In this manner it was possible to highlight a household's various positions within the different fields in terms of their access to capital. The role of fields in capital accumulation is also identified. This part of the analysis dealt with access to accumulation of economic and social capital that had relevance for food production and nutritional outcomes. Social field theory is applied in the analysis of social inequalities in nutrition and how different forms of capital and capital accumulation function and exist in relation to social fields. The study concerns mainly economic and social capital and not cultural capital. Similarly it deals with links between social organisational aspects of fields and nutrition and does not directly address the issue of cultural aspects of social fields.

3.10 Ethics

Ethical approval for the historical longitudinal Bwamanda study had been granted by the University of Leuven's Tropical Childcare Health Working Group. Community and individual verbal consent was obtained from children's carers. Ethical approval was also obtained in 2014 from the Ethical Committee at the School of Public Health at the University of Kinshasa (annex 3).

For Paper III ethical clearance was granted by the Regional Committee for Medical and Health Research Ethics, Western Norway (annex 4). In addition, ethical approval was obtained from the Ethical Committee at the School of Public Health, University of Kinshasa. (annex 5). An informed consent information sheet and form was prepared in Ngbaka language (annex 6). On the basis of a discussion around these forms verbal informed consent was obtained from the study participants including consent to record the interviews. Consent

was acquired prior to conducting the interviews. The study describes selected households in some details. In order to strengthen confidentiality, household names are not used. Links to any locations are also disguised. For ethical reasons only households with malnourished children who had been treated and later recovered from malnutrition were recruited to the study.

4. Results

4.1 Paper I: Incidence and course of child malnutrition according to clinical or anthropometrical assessment: a longitudinal study from rural DR Congo

Paper I describes associations between season, age, gender and clinical and anthropometric malnutrition. It also describes the course of malnutrition in terms of shifts in severity of and duration of malnutrition.

The study found seasonal differences in malnutrition. Incidence rates for marasmus and anthropometric malnutrition were highest in the rainy season and rates for kwashiorkor were highest at the end of the early rainy season. Furthermore, the incidence rates for McM were highest in the dry season, declining at the beginning of the rainy season and increased at the end of the rainy season.

The incidence rates of McM were higher in boys than girls, and differences between boys and girls were also found for marasmus. These differences are significant for McM in the dry season post-harvest [for boys 41.3 per 1000 child-months (95%CI: 35.4, 48.2) vs. for girls 28.7 per 1000 child-months (95%CI: 23.8, 34.7)], and in marasmus in the dry season [12.0 per 1000 child-months (95%CI: 9.0, 16.1) in boys, 3.5 per 1000 child-months (95%CI: 2.0, 6.0) in girls]. In contrast there is a significantly higher incidence of moderate stunting in girls than in boys at the end of the rainy season, post-harvest [for girls 22.2 per 1000 child-months (95%CI: 19.0, 26.0) vs. for boys 15.6 per 1000 child-months (95%CI: 13.0, 18.7)]. For other forms of anthropometric malnutrition there are no significant gender differences.

Age is a factor that influenced incidence rates of malnutrition. The incidence rates increased from the 0–5 to the 6–11 age categories. McM and marasmus had, in general, a higher incidence for all ages than their anthropometrical counterparts, moderate and severe wasting. There is a tendency of the rates to decline with increasing age, but for McM, moderate wasting and marasmus, this decline was "delayed" until the age of 36 months. Incidence rates of moderate and severe stunting were very high up to the age of 12 months.

Shifts back to normal nutritional status within 3 months were more common for clinical than for anthropometric malnutrition (62.2 to 80.3% compared to 3.4 to 66.4.5%). The proportion of moderately stunted children that shifted back to normal status was low [30.9% (95%CI: 27.4, 34.4)] and only a small minority of severely stunted children shifted back to normal status [3.4% (95%CI: 1.9, 4.9)]. The study describes the duration of moderate forms of malnutrition according to the season of when malnutrition episodes started. It does not find any significant variances between McM and moderate wasting. Most of the episodes of McM and moderate wasting resolved after 3 months. After 3 months, 64.4% to 76.7 % of the McM, depending on the season, and 69.2% to 78.3% of the moderate wasting cases resolved. Few cases of moderate stunting resolved and a large percentage of children with moderate stunting remained stunted after 9 to 12 months.

4.2 Paper II: Diet and kwashiorkor: a prospective study from rural DR Congo

Paper II describes the food items consumed by the children according to their nutritional status. The proportion of children who consumed food items such as snails and eggs is non-significantly higher among children with kwashiorkor than for well-nourished children and children with marasmus. Conversely, the proportion of children who had consumed items such as okra, ground nuts, meat and fish is non-significantly lower for children with kwashiorkor than for the rest. The diet of children who developed kwashiorkor is characterised by a significantly low consumption of sweet potatoes, papaya and "other vegetables." The category "other vegetables" includes taro, taro leaves and wild food (annex 7). In comparison, the consumption of these food items is higher in children who did not develop kwashiorkor. Their consumption is also higher in children who developed marasmus than in children who developed kwashiorkor.

Sweet potatoes and papaya have a high β-carotene content. The study finds that a risk model containing age function, length/height-for-age Z-scores, consumption of sweet potatoes, papaya or "other vegetables", duration of this consumption and its interaction term, is the most plausible model. Among children aged 10-42 months, the risk of developing kwashiorkor increased the longer these food items were not consumed. The analysis was repeated with children who only developed marasmus as the reference series: this analysis yields similar results.

4.3 Paper III: The social context of severe child malnutrition: a qualitative household case study from a rural area of the Democratic Republic of Congo

Paper III investigates the linkage between the socio-economic context and child nutrition. It identifies social fields and shows how four fields have implications for food production and nutrition. In this manner the paper explains why some households succeeded in ensuring that their children were well-nourished while others failed.

Social fields

Four social fields with implications for child nutrition are identified including the household, the *gbisa* inter-household cooperation, the village and the local NGO. These four social fields extend in social space and have their own unique characteristics. Food production and consumption is associated with the household compound and household agricultural plots; access to external labour and capital with the neighbourhood; acquiring land with the village; and social service provision with local NGO activities. The latter activities are also linked to activities at the national and international level. Several characteristics are unique to these four fields. The household is the major unit for food production and consumption. Division of labour along gender lines and household size/composition influences a household's ability to produce sufficient and adequate food. Neighbourhood cooperation in the form of *gbisa* work groups is characterised by being a reciprocal group for exchange of labour. In order to mobilise a work group the host would have to serve the food required by the participants. Among the better-off households, the *gbisa* is an important vehicle for capital accumulation. The village is associated with access to land with land being transferred from father to sons. Living in a village and continuously cultivating the land are preconditions for access to land. The local NGO, CDI-Bwamanda, in the absence of a strong state has become the main provider of social services. It had once received assistance from several international donor organisations but due to a decline in financial assistance from these donors, the organisation has had to scale down its operation. The NGO's provision of social services established links between local activities and processes at the macro socio-economic level.

The household

The vulnerability of households to child malnutrition is linked to their access to farm labour which again relates to household size and composition. Larger households with relatively

many adult members were able to supply their families with sufficient and adequate food. These households could diversify their activities with household members specialising in horticultural activities, making wine, hunting and fishing. Small nuclear families are vulnerable and when adult members became sick the household is at risk of food insecurity and malnutrition. Given that agricultural work is divided along gender lines households with unbalanced gender composition are susceptible to food insecurity and malnutrition.

Inter-household cooperation – gbisa

In Bwamanda the *gbisa* is an important inter-household institution for mobilising labour and households overcome seasonal bottlenecks by mobilising work groups. In particular, work groups play an important role during land clearing and weeding. In order to mobilise *gbisa* the host is required to provide work group members with food. Failure to participate in *gbisa* relates to inability to provide the food required by the *gbisa* members and being considered by other farmers as unable. Households that do not take part in *gbisa* are at risk of food insecurity and malnutrition. In Bwamanda the *gbisa* is also an institution for capital accumulation. Income from the *gbisa* is invested in livestock, bicycles and sewing machines.

The village

Among the Ngbaka, access rights to land is closely linked to the village as a unit. In the study, households with well-nourished children had access to land and labour and wealthier households had access to a relatively large area of land. In Bwamanda there are few alternative income opportunities. Landless households may therefore depend on work for food or harvest palm oil fruit on other farmers' fallow land. Such households are at risk of food insecurity and malnutrition.

The local NGO

To fill the gap left by public service provision a local NGO, CDI-Bwamanda, has provided social services to people in Bwamanda. The local organisation used to play an important role in providing agricultural extension. As a result of diminishing funding the CDI-Bwamanda has had to scale down its operation. The study indicates that access to the limited services that existed was disproportionately associated with wealth. Households with well-nourished children benefitted from services in areas such as agricultural extension, hygiene and access to clean drinking water, while households with malnourished children benefitted less. There

are also constraints on access to health services and the long distances to services and relatively high medical fees could put constraints on a households' ability to utilise the services for treatment of child malnutrition.

5. Discussion

The first part of this discussion addresses issues related to the theoretical approach and methodologies applied by the thesis. A conceptual framework has been formulated to analyse how factors at different levels influence malnutrition and the discussion shows how the framework can be used integrate determinants at different levels. The thesis also discusses how social field theory can be used in combination with the framework to separate out underlying and basic determinants of malnutrition and analyse how social fields at these levels have implications for child malnutrition. Several methodological topics will also be discussed including the use of a mixed method, sampling techniques and nutritional assessment. Finally, the results of the three papers are discussed in light of other research findings

5.1 Determinants of malnutrition and the use of the conceptual framework on malnutrition

This thesis has used a conceptual framework for malnutrition to guide the analysis and structure the discussion on research findings. The framework points to potential associations between different variables and nutrition. The quantitative longitudinal study data have been used to examine the associations between nutrition and variables such as age, gender and seasons. The data have also been used to analyse determinants at the immediate level and investigate dietary determinants of kwashiorkor. The use of the conceptual framework allows for the investigation of child malnutrition in Bwamanda as a disorder with a multi-factual origin. It facilitates the specification of the many factors that are involved in the development of malnutrition and clarifies how determinants at different tiers are interlinked. It makes possible the use of different research methods and the thesis demonstrates how epidemiological and social science methods can be combined in the study of malnutrition. In line with the framework, this thesis investigates determinants at three levels including immediate, underlying and basic level.

At the immediate level the thesis demonstrates the link between diet and malnutrition, exemplified by the dietary factors in the development of kwashiorkor. The diet in Bwamanda is monotonous, and maize and cassava are the two major food items consumed in the area.

Complementary feeding is also based on these two food items. Paper II shows that children of a young age who do not consume food items such as papaya, sweet potatoes and what has been termed "other vegetables" are at a high risk of developing kwashiorkor.

The immediate determinants are, in turn, influenced by underlying factors including food security. The thesis dwells on food production and the social organisation of food production in particular. Paper III shows how households with insufficient access to labour and land are at times unable to produce sufficient and adequate food. Children living in these households are therefore at risk of malnutrition.

In an environment that is characterised by household food insecurity it is especially toddlers and young children that are exposed to malnutrition. As shown in paper I, children below the age of 24 months are at particularly high risk of malnutrition; after this age the risk drops. The study also points to seasonal variations in food insecurity and Paper I suggests that the high incidence of mild to moderate clinical malnutrition (McM) prior to the first harvest of maize might be related to food shortages during "the hungry season."

The basic level forms the context of determinants located at the immediate and underlying level. Paper III highlights how limited access to public services puts constraints on food production and is related to malnutrition. Restricted local development is again related to the state's inability to drive development efforts forwards.

5.2   Social field theory as a tool for analysing determinants of nutrition

In its analysis, this study combines the conceptual framework on malnutrition with social field theory. Data from the qualitative household case study are used in a multi-level analysis of underlying and basic socio-economic factors that influence nutrition (figure 12). Field analysis complements the framework and social field theory can be used as a tool for identifying social units with structural consequences for the individual and society as a whole. In this study, these entities are fields with implications for food production, consumption and nutritional outcomes. There are several advantages to using social field theory in a multi-level analysis of malnutrition.
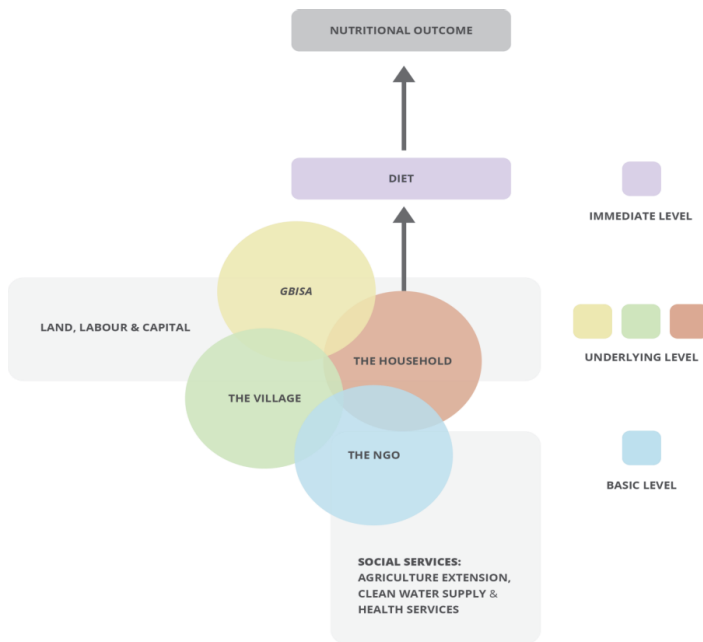
Figure 12 Social fields with implications for nutritional outcome at underlying and basic levels

Field theory allows for the use of different qualitative methods to gather open-ended information on social life in order to identify social fields at micro and macro levels that has structural implications [216, 217, 222]. The method can therefore be used to capture the multifaceted chain of interconnections involved in malnutrition. Attempts have been made to investigate these connections by applying statistical analysis. As an example, a graphical chain model has been used to analyse quantitative data and demonstrate the complex dependency chain that is involved in the determinants of child malnutrition [53]. No methods have been suggested for how qualitative data can be used in a multi-level analysis. This study (paper III) shows how qualitative data on tasks and teams involved in food production can be used to identify social fields with consequences for nutrition. It also shows how it is possible to draw on field theory in order to demonstrate how factors at the underlying and basic levels influence nutrition.

Field theory can be used to explore how determinants at the local level affect nutrition and to identify underlying determinants of malnutrition. Food security has been recognised as a

central determinant of nutrition, and by examining social organisational issues related to food security, local fields can be identified. From examinations of the social organisation of food production, this study identified three local social fields with implications for nutrition. These three fields are the household, the *gbisa* and the village.

Field theory enables an analysis of how events at the local level are connected to processes at the macro level. It can therefore be used as a tool for analysing links between underlying and basic level determinants of malnutrition. In this study, the local NGO is identified as a field that established a linkage between the local level and the macro level. The NGO has filled a gap in public service provision and the organisation is related to a number of national and international organisations. Food production and nutrition in Bwamanda is thereby linked to a number of distal factors. Social field theory has also been used to analyse the state as a separate field that, through its legal system and its officials, regulates social life [216, 222]. In most countries state representatives are present in most localities [216]. In the DRC however, the state is characterised by its absence rather than its presence. The state can be recognised as a social field with consequences for children's nutritional status in Bwamanda. As a result of factors such as poor governance, uneven distribution of services and infrastructure and national conflicts, the national and local governments have failed to initiate and sustain development efforts in rural areas such as the Bwamanda. The government's inability to drive small-scale agricultural development efforts forward has had negative implications for child nutrition in Bwamanda.

Social field theory can be used as a tool for analysing inequalities in nutrition. Fields are associated with different forms of capital and accumulation [223, 224]. They have structured positions and the occupants have different resources and dispositions [225]. This study illustrates how fields can be related to various forms of capital and resources. Access to resources including land, labour and capital and to services for adequate food production is related to four social fields. The households had unequal access to these resources.

Nutrition can be studied from a cultural perspective using social field theory. According to the theory, the separate fields are associated with unique symbols and forms of communication. In addition, social fields are considered as arenas where people compete for the distribution of cultural capital. This study deals with social organisational aspects of nutrition and does not directly address cultural aspects of nutrition. Cultural aspects of child

malnutrition have been dealt with by other researchers and a study from Tanzania describes how malnutrition was associated with shame [172].

Determinants of nutrition at different levels are closely intertwined and it might be difficult to separate underlying factors from basic factors. Social field theory is a method that can be applied to distinguish better between factors at these different levels. In this study, four social fields are delineated with extension in social space and unique characteristics. The fields are considered as existing through their effects on households. The linkage between the social fields and nutrition is illustrated in household cases that describe households with malnourished and households with well-nourished children. The household cases are therefore useful in order to define field boundaries and where one field begins and another ends.

5.2 Design

This thesis used data from a quantitative longitudinal study and investigated a set of determinants of malnutrition including age, gender, seasons and diet. It investigated malnutrition in a remote rural area in the DRC where malnutrition is widespread. So far there has been little research in this area and there are very few studies on the Ngbaka ethnic group.

The thesis applied a sequential mixed method approach and the quantitative study was followed by a qualitative study. The quantitative study contains information about children's health status and diet related to the immediate level of malnutrition, but contains limited data about factors that could be used to analyse underlying and basic determinants of malnutrition. By using a mixed method approach the qualitative household case study could compensate for this weakness and highlight how underlying factors and basic factors influence children's nutritional status. In particular, the approach allows for an understanding of links between nutritional status, diet, social organisation of food production and macro socio-economic conditions. In communities where agriculture is the dominant livelihood there is a close relationship between the social organisation of agriculture and nutrition, and the qualitative study could draw attention to this relation.

It is also a strength of the thesis that the quantitative data and the qualitative data were collected in the same area and from among the same ethnic group. The culture and the social organisation of the Ngbaka are to some extent unique for this group. Whereas the Ngbaka are agriculturalists neighbouring groups are more dependent on hunting and the social organisation and culture of these groups differ from those of the Ngbaka. In consequence, the social determinants of nutrition may be different from one area to another and it was therefore necessary to collect data for the qualitative study in the same area as the quantitative study was conducted.

A weakness of this thesis is that there was a long period between when the data for the quantitative study were collected and when the qualitative study was conducted. If Bwamanda had experienced major development during the period from 1989/91 to 2012/2013 this could have reduced the relevance of the qualitative study. Bwamanda is located in a remote area and the infrastructure is poor. This weakens links between Bwamanda and other areas and restricts the possibility of economic development, for example through cash cropping and export. Public services are few and since 1968 the same NGO has provided services to the area. In consequence, changes between the period the quantitative longitudinal study was conducted and the time the qualitative household study was undertaken appear to have been few. The people still depend predominantly on traditional subsistence agriculture and their diet remains the same.

A second weakness is that the qualitative study mainly concentrates on the relationship between food production, diet and malnutrition. To a limited extent, the qualitative study focuses on social determinants related to age and gender. The study does not pay much attention to the issue of child care and cultural aspects of nutrition. A stronger emphasis on such factors would have strengthened the thesis.

Thirdly, the qualitative study could have been followed by a contemporary quantitative study. In this manner the variables that had been identified would have been applied in a study that created quantitative evidence of the relationship between variables such as access to labour, land, capital and social services and nutritional outcomes in Bwamanda.

5.3 Design effect

Papers I and II are based on a study that used random cluster sampling techniques and the village was used as a unit for cluster sampling. When the study was carried out there were 52 villages and 16 of these were randomly selected. Bwamanda is a relatively homogenous area as to geography and livelihood adaptation. Spatial and socio-economic variations with implications for children's nutritional status that the study did not capture could have existed. At the time when the random sampling was undertaken there was a risk that heterogeneity between the cluster's means could have existed. If this is the case, this could lead to artificially inflated precision in comparison to precision obtained on the basis of a simple random sample [228].

5.4 Precicion, accuracy, sensitivity and specificity of measurement

Errors occur in nutritional measurements and errors affect precision and accuracy. Random errors affect the precision in nutritional measurements and commonly result from inadequate training, instrument errors and difficulties in making the measurement. The problem of random errors can be reduced by employing trained personnel, using standardised equipment and precise calibrated instruments [229]. For Papers I and II the data were collected by two well-trained examiners throughout the study and this reduced the risk of random errors. Technical error of measurement (TEM) is commonly used to assess the precision of anthropometric measurements. TEM is defined as the standard deviation between repeated measurements taken separately by one observer or between measurements carried out by several anthropometrists. In this study TEM was not collected and this might have restricted the study's ability to quantify imprecision in the anthropometric measurements.

For Papers I and II the data used for clinical malnutrition were recorded by examiners that had been trained in detecting clinical malnutrition. Still the training did not involve standardisation during which a number of observations are compared and inconsistency identified.

Paper III is based on the occurrence of marasmus and kwashiorkor identified by medical doctors employed at Bwamanda hospital. The doctors work in an area where marasmus and kwashiorkor are widespread and many children are hospitalised for marasmus and

kwashiorkor. Households with well-nourished children were identified by the nurses at a health centre. According to the nurses the children of these households were known to not have suffered from marasmus or kwashiorkor. The information obtained from the nurses may have been susceptible to recall bias.

In the longitudinal study, age was determined by use of birth certificates and an events calendar. In Bwamanda, women give birth to children either at home or at a health station, whereas very few give birth at the hospital. There is therefore a risk that an incorrect date of birth has been recorded on a birth certificate. Seasonal calendars were used to determine some of the children's age. In this manner the risk of errors in determining the children's age increased. Only 10% of the children's age was determined in this way.

Systematic errors affect the accuracy of nutritional measurements. Commonly, systematic errors are caused by equipment bias. It is difficult to estimate accuracy because the correct values in nutritional measurement are not known [229]. In the longitudinal study the same equipment was used to measure weight and height of children throughout the study. In this manner the risk of equipment bias was minimised. A locally-made measuring board was used to measure the length of the children. The ability of the study to produce valid measurements of children's length therefore depends on how the measuring board was constructed. But consistent calibration of all instruments before each measuring session should have minimised the risk of bias. Accuracy in anthropometric measurements can be estimated by comparing the measurements with those made by a highly skilled person in standardised measurement techniques [230]. The study did not assess the measurements made by comparing them with those done by a criterion anthropometrist and this could have increased the risk of systematic errors. In longitudinal studies systematic errors can occur when different persons undertake the measurement during the different sequences. Having one person carrying out measurement eliminates this risk of between-examiner errors occurring. Paper I describes the incidence of malnutrition and the data were obtained from two sequential survey rounds. The data on incidence are therefore at a higher risk of measurement error because they relied on two possible sources of error. Two persons conducted the measurements and the use of only two persons carrying out the anthropometric assessment reduced the risk of systematic measurement errors.

Sensitivity of an indicator refers to the indicator's ability to identify and classify persons as malnourished. The specificity of an indicator concerns the indicator's ability to identify and classify persons who are well nourished. Clinical assessment of malnutrition is typically conducted in low-income countries, but is less common in high-income countries. In general, clinical assessment is a cost effective method to detect malnutrition in a context where financial resources are limited. Paper I describes three forms of clinically defined malnutrition including moderate malnutrition, marasmus and kwashiorkor, while papers II and III describe marasmus and kwashiorkor. The most typical signs are used for detecting these forms of malnutrition. Physical assessment of malnutrition has some limitations and non-specificity is a key issue [229]. Marasmus and kwashiorkor are severe forms of malnutrition identified by well-defined signs. Problems with regards to physical examinations predominantly occur in the detection of mild forms of malnutrition. Detection of moderate clinical malnutrition (McM), as used in paper I, is most susceptible to bias.

5.5 Limitations in the use of dietary assessment

Data on diet for paper II are based on a non-quantitative recall of foods consumed during the previous 24 hour period [229]. This was done by asking carers about their children's food consumption. In order to capture variations in food consumption or seasonal variations, recalls can be repeated over a longer time period. The problem of cognitive processes in food recalls has been addressed and it has been argued that recalls tend to be based on generic knowledge rather than specific knowledge [231]. The 24 hr. recall introduced a fixed list of food items, which may easily omit some food items, some of which may even be important food items. This problem can be addressed by introducing very detailed 24-hr recalls, but study populations do not often tolerate very extensive questionnaires and there is a fast decline in marginal gain in information acquired with increasing the details in the questionnaire [232, 233].

The list of food items used in the longitudinal study was not sufficiently detailed and paper II was not able to specify food items recorded under the category "other vegetables". In Bwamanda, taro is one of the commonly grown crops, but the questionnaire did not list taro or taro leaves. Children's consumption of taro and taro leaves was therefore recorded under the category "other vegetables". Taro leaves contain β-carotene [234] and the consumption

of taro leaves may therefore have protected against kwashiorkor. The Ngbaka depend on the consumption of wild food items and these play an important role during "the hungry season", but the list excluded wild vegetables and fruits. Consumption of wild fruits and vegetables common to the area was therefore also recorded as "other vegetables". Wild food items typically collected in the area include 13 different leaf species, 5 different tuber species and 13 different fruit species (annex 6). Wild food is also known to supply proteins, minerals, vitamins B_1, B_{12}, B_2, and C and preformed vitamin A [235]. Consumption of wild food can therefore have played a role in the protective pathway of kwashiorkor. Furthermore the study assumes that the food items reported at a given point in time were consumed before the next survey round. Food consumption is characterised by individual variances and therefore the assumption represents a weakness. Finally, given that the 24 hr. recall was non-quantitative it was impossible to calculate the nutrient content of the food consumed by the subjects.

5.6 Validity, relevance and reflexitivity in the qualitative research

Qualitative research is assessed with reference to several criteria including validity, relevance and reflexivity. These issues are addressed in the following sections.

Internal validity

The concept of internal validity concerns truthfulness and to what extent research findings are supported by other research findings [236]. Triangulation is commonly used by researchers to establish validity in research and the method has been described as a method of highest priority in determining internal validity in qualitative research [237]. Triangulation was applied during collection of data for paper III and the data collection involved participant observation, semi-structured interviews at focused group discussions and key informant interviews. Through the use of triangulation the study was able to shed light on an issue from different perspectives. The major methods used for this study were in-depth interviews, participant observation and group discussions. There are several examples of how the combined use of different methods improved the quality of data. For instance, during group discussions, participants argued that some men and women were "lazy" and did not participate in work groups and these farmers therefore achieved low yields. Yet, in in-depth interviews with farmers who did not take part in work groups, they said that they could

not afford to provide the food items required by work group participants in their area including meat and fish. They were therefore not in a position to organise work groups. At times information obtained from interviews were confirmed through the use of participant observation. For example, farmers reported during in-depth interviews that in order to achieve good yields it was crucial to properly weed the fields. Shortage of household labour during critical agricultural periods put constraints on weeding operations. During farm visits comments were made on the poor growth of maize in parts of the maize fields. A typical reply during such visits would be that poor growth was a result of insufficient female labour for weeding the maize fields.

Relevance

Relevance of the research project concerns the implication of the project [238]. The research on social determinants should be seen as a part of a larger project on determinants of the development of child malnutrition. The study of social determinants is of particular importance to understand how factors at underlying and basic levels influence the development of child malnutrition and place the problem into a wider socio-economic context. The research results therefore have implications for nutrition interventions that address the problem of malnutrition in Bwamanda and similar rural areas in the DRC.

Reflexivity

The research topic selected and the angle of investigation are influenced by a researcher's background [239]. Research on social determinants also reflects a researcher's previous professional background. With a background in social anthropology and agricultural extension projects, I have a special interest in household food production. In addition, I have developed an interest in the relationship between diet and child malnutrition. This may have led to an overestimation of the importance of food production as a cause of child malnutrition while other factors may have been underestimated.

Recruitment and data analysis

The informants for paper III were recruited using purposive sampling. The children who had suffered from kwashiorkor and marasmus were identified and recruited by the Bwamanda hospital medical doctors. The identification was initiated during the visit to Bwamanda in October 2012 and completed in February 2013. Permission to undertake the interviews was granted by the village chief (capita). Nurses at the health stations also facilitated contact with

the interviewees. The households with well-nourished children were identified by the nurses at one health station. The participants for the group discussions were identified by the village leaders in the location where most of the severely malnourished were residing.

In retrospect, I realise that it would have been beneficial to have increased the number of kwashiorkor cases. Identifying the peers of households with former kwashiorkor and marasmus was very slow. The recruitment process could probably have been more efficient if it had been carried out through the health centres. Transport was also a limitation and travelling back and forth on motorbike to the households on very poor roads was time-consuming and sometimes tough. I could also have stayed longer in the area during the period of household interviews.

During the field work, interviews and questions were raised in English and translated to Ngbaka and the answers translated back to English. The interviews were recorded and the recorded interviews were reviewed. On the basis of these reviews, I identified imprecise answers and formulated new questions to be posed during re-visits to the informants. The interviews were not transcribed. This constitutes a major weakness and some information and nuances could have been missed.

Applicability of qualitative findings

The research was carried out in a relatively remote rural area where subsistence agriculture is the major livelihood adaptation. The study context is crucial to the extent that study findings can be extended to other settings. In qualitative research there are different opinions about the importance of generalisation. The literature emphasises that the value of qualitative research lies in the particular description and the particular themes developed in context of a specific site [240]. According to this position the knowledge is idiographic and is to be found in the particulars [241]. Other scholars emphasise the importance of findings being applied in practice [242]. As with statistical analysis, the end product of qualitative analysis should lead to generalisation [243]. There are different models of generalisability and the literature distinguishes between three major models including extrapolating, analytical generalisation and case-to-case translation [244]. The third model is often referred to as transferability and is relevant for the findings in Paper III. According to this model, proximal similarity supports transferability to those people, settings and socio-economic political context that are most like the setting in the focal study [241]. In the DRC child malnutrition is widespread in rural

areas. In these areas people are predominantly practicing subsistence agriculture. The findings could therefore be transferable to many rural areas in the DRC. They would also be transferable to other areas in low-income countries where subsistence agriculture is practiced. The findings are less relevant for rural areas that are characterised by cash cropping and where household food security relates to market access to affordable nutrient-rich food.

Then again this thesis describes institutions that are unique to the Ngbaka. Although the literature describes the importance of work groups among various ethnic groups in Africa, the *gbisa* arrangement is apparently rather unique to the Ngbaka. The institution is also closely related to food production and children's nutritional status in Bwamanda. This fact might, to some extent, reduce the possibility of transferring the findings to other areas.

This thesis has applied social field theory in the study of nutritional outcomes. It therefore goes beyond the description of social factors influencing the development of child malnutrition in Bwamanda. The study proposes that the approach of social field theory in the study of nutritional outcomes can be extended to the study of how social factors are associated with other health outcomes

5.7 Major research findings

The following sections discuss the major research findings. At the immediate level it addresses the issue of diet and the development of kwashiorkor. In terms of underlying factors, food security and three social fields related to factors at this level, namely the household, the *gbisa* and the village, are dealt with. Season, age and gender as determinants of nutrition are also discussed at this level. The last part of the discussion concerns basic factors and the socio-economic context of malnutrition in the DRC. In this study, one field, the local NGO, is associated with this level.

5.7.1 Diet and the development of kwashiorkor

In Bwamanda, maize and cassava are the most important staples grown and local diet is also based on these two crops. The monotonous diet consumed in Bwamanda exposes the children to malnutrition including severe malnutrition. The literature has related marasmus to

energy deficiencies and kwashiorkor to protein deficiencies [66]. Paper II does not find any significant differences in the proportion of protein-rich food consumed between children with marasmus, children with kwashiorkor and well-nourished children. These findings are in line with other observational studies where results have not been in favour of the protein-energy hypothesis [72, 188].

There is an agreement that both kwashiorkor and marasmus are results of severe undernutrition, but undernutrition leads to two different syndromes [245, 246]. According to the free radical hypothesis there is a general deficiency in protection against free radicals in kwashiorkor, caused by a deficiency in micro-nutrients [75]. The hypothesis has been challenged in observational and experimental studies. A longitudinal study examined the diet of Malawian children below three years [189]. The authors studied children vulnerable to kwashiorkor every two weeks for ten weeks to determine whether they developed kwashiorkor or not. The investigation applied a food frequency questionnaire and estimated intake of nutrients. The study found that the daily intake of vitamin A equivalents was low among children who developed kwashiorkor, but not significantly lower than in the control group. A case-control study examined the antioxidant hypothesis by comparing the diet in siblings of children presenting with marasmus and children with kwashiorkor [188]. The study wanted to investigate if children with kwashiorkor consumed a diet with less micro-nutrient and antioxidant-rich food such as fish, eggs, tomatoes and orange fruits. It concluded that siblings of children with kwashiorkor consumed eggs and tomatoes less frequently than children with marasmus but the differences in consumption between the two groups were minor. The indirect method of studying diet in children with kwashiorkor was a weakness in this study. A randomised, double blind, placebo controlled trial from Malawi, assessed the efficiency of antioxidant supplementation in preventing kwashiorkor in children aged 1–4 years [81]. The intervention arm received antioxidant powder containing riboflavin, vitamin E, selenium and N-acetylcysteine, while the control arm received a placebo of an identical looking powder. According to the authors the study showed that the supplementation of antioxidant powder did not prevent children from developing kwashiorkor. The study did not include supplementation of provitamin A and thus the study did not address the efficiency of provitamin A in preventing kwashiorkor.

In contrast to the above research, Paper II finds that the diet of children who did develop kwashiorkor differed from the diet of children who did not develop the disease. In

comparison with the diet of well-nourished children as well as children with marasmus the diet of children with kwashiorkor featured a low consumption of sweet potatoes, papaya and "other vegetables". These food items are characterised by high β-carotene content [234, 247-250]. The risk of developing kwashiorkor increased the longer the child had not consumed these food items. The paper therefore suggests that the consumption of a diet that includes food items containing β-carotene is in the protective pathway of kwashiorkor. Findings described in paper II therefore support the free radical hypothesis. The importance of β-carotene is emphasised because it is a substance with significant antioxidant activities and intake of β-carotene has been related to the prevention of several diseases [250]. A large body of epidemiological evidence has supported the benefits of antioxidants by preventing oxidative stress and a low level of plasma β-carotene has been associated with increased mortality [251-253]. Sweet potatoes, papaya and what we have termed "other vegetables" contain several other carotenoids that have antioxidant activities. The various carotenoids, the mixture of carotenoids or carotenoids in association with other antioxidants in these food items may have played important roles in the protective pathway in kwashiorkor.

5.7.2 Food and nutrition security

The household

Household characteristics

Food security is considered an underlying factor with implications for children's nutritional status and is manifest at the household level. Paper III shows how a household's organisation may relate to food and nutritional security and demonstrates a linkage between household size, composition and nutritional outcomes.

The literature on farm household size and food security is inconclusive. Some research has found larger farm households to be food secure [97-99, 254-256]: a large family size can positively influence food security because it generates a labour supply and households with sufficient labour are thus less likely to be food insecure [89]. Household labour demand also varies in accordance with what type of agriculture is being practiced and it has been argued that larger extended families are effective for practicing shifting cultivation whereas smaller units are suitable for intensive agriculture [96, 101]. Labour demand is also influenced by the environment in which the farmers operate and in a setting where the resources are widely dispersed it is anticipated that larger units are more effective than small [102]. Furthermore a household's capacity to produce enough food relates to its dependency ratio and households with a high dependence ratio might have difficulties in sustaining themselves [103-105].

The Ngbaka live and work in an environment where resources are widely dispersed. In Bwamanda there are hardly any local means of transportation and farmers walk for several hours to reach their farms and fishing grounds. They also practice an intensive form of shifting cultivation. This environment favours large families with a low dependency ratio. Paper III illustrates how larger households with many adult members can diversify their food production and thereby improve food and nutrition security. In contrast, nuclear families are vulnerable and the implications of ill health are shortage of labour, food insufficiency and malnutrition.

It is not only the size of the household that influences food and nutrition security but also composition. Among the Ngbaka, labour is divided along gender lines and this thesis and

Paper III demonstrate how an unbalanced gender composition can have negative implications for food production. It shows how insufficient male labour may reduce a households' ability to clear land. Among the Ngbaka, women hold the major responsibility for weeding and paper II indicates a relationship between insufficient female labour, food insecurity and malnutrition. Inadequate weeding is considered to be among the major factors in sub-Saharan Africa that causes low yields [257]. The findings align with the notion that gender division of labour in agriculture has important implications for food production and nutrition [96, 109].

Temporary household food security

Research has reported that malnutrition tends to occur in the annual "hungry season" when the previous season's harvest stocks have dwindled [258]. Households adress this problem by collecting wild food and it is poor households in particular that rely heavily on the collection of wild food [259, 260]. Farmers in Bwamanda harvest maize twice per year with the first harvesting at the beginning of June whereas the second harvest takes place in August. Shortage of food is severe prior to the first maize harvest and during this "hungry seaon" farmers collect a variety of wild plants. Wild food also plays an important role in the diet during the end of the rainy season, when people collect and consume caterpillars. Paper I finds seasonal variations in malnutriton and that the incidence of moderate clinical malnutrition (McM) is high during the period prior to the first harvest of maize. On the other hand the incidence of wasting and stunting is highest in the rainy season. In line with other research, paper I suggests that this high incidence of wasting and stunting could be related to increased morbidity due to diarrhoea and malaria in the rainy season [143, 181, 182]. In conclusion, the high incidence of child malnutrition in Bwmanda appears to be associated with the rainy season and only McM is related to the agricultural season. This may be a consequence of households that are vulnerable to food insecurity and malnutrition succeeding in overcoming the problem of food shortages prior to the first harvest of maize by relying on wild food.

Gender inequalities in food and nutrition security

Although households may appear as food secure, individual members in these may be food insecure and at risk of malnutrition. The literature has paid particular attention to the discrimination of girls in food allocation, but research on gender inequalities in sub-Saharan Africa is inconclusive [136, 137, 139, 186]. During the field work in Bwamanda no

information indicated that there was any discrimination of children based on gender and this observation was confirmed in key informant interviews. This observation was maintained in paper I and the findings concerning gender differences in nutritional status are inconclusive. The findings show higher incidence of McM and marasmus in boys than girls in some seasons. On the other hand, incidence of moderate stunting is significantly higher in girls than in boys at the end of the rainy season, post-harvest. No significant gender differences in other forms of anthropometric malnutrition are found.

Household food security and the risk of toddlers and young children becoming malnourished

Toddlers and young children in Bwamanda reside in an environment where there is a high risk of household food insecurity. The diet is monotonous and the complementary food is made from maize porridge and cassava stew and it is likely that the low nutrient density of weaning food increases the risk of malnutrition and in toddlers and young children. This risk is increased by the early introduction of complementary food. Other studies have found that child nutrition is very sensitive to environmental factors and growth is very sensitive to such factors during a child's first two years of life [185]. Studies have found HAZ-scores to decline dramatically at the age of 24 months [183, 261]. The findings of paper I are in line with these findings and the study finds a high incidence of malnutrition at infancy and that the rates tend to decline with increasing age. The incidence of moderate and severe stunting was particularly high at a very early age.

Inter-household cooperation – gbisa

In accordance with reports from other areas, Paper IIII shows how reciprocal work groups can be used to mobilise agricultural labour and solve seasonal bottlenecks [122, 262-265]. There is therefore a link between participation in such groups and household food security, with households that take part in such groups tending to be food secure.[105, 111].

In Bwamanda working groups could be mobilised to solve tasks such as land clearance and timely weeding. In this study, households with well-nourished children had solved the problem of unbalanced gender household composition and labour shortages by organising work groups. In order to mobilise reciprocal work groups the host is expected to serve food and alcoholic drinks [122]. Paper III shows that farmers who are not in the positon to serve

the food required by the group members cannot host work groups and failure to participate in such work groups is related to an inability to provide an adequate diet and thus incur malnutrition.

Reciprocal groups can also be organised for other purposes than mobilising labour [121]. Among the Ngbaka reciprocal groups can play a role in capital accumulation with capital invested in livestock, sewing machines and bicycles. In consequence, farmers who participate in *gbisa* can further enhance and diversify their livelihood. Researchers have argued that reciprocal work groups are primarily a tool for mobilising labour and cannot be a useful tool for rural development [122, 266]. It is argued that the groups are subsistence oriented, based on reciprocity and the trend is towards wage labour. This thesis, however, illustrates how the *gbisa* has the potential to play a role in local development. *Gbisa* for capital accumulation can, for example, evolve into groups that promote different types of agricultural activities including livestock keeping. In addition, the *gbisa* and similar forms of neighbourhood cooperation found in Bwamanda developed into groups that promoted cash cropping, better education and improved health services.

The village

Access to productive land is considered to be one of the most important factors determining household food security and the landless would be vulnerable to food insecurity [125, 267, 268]. Land availability is considered to be a problem in the DRC and although there is great potential to cultivate land in the DRC, farmers report difficulties in accessing land [269]. Research has noted that access to agriculture land plays a role in determining children's nutritional status and that children of landless agricultural workers are more likely to be malnourished than those of land owners [270, 271].

In Bwamanda there is a close link between the village and access to land; land is administered by the village leadership and farmers obtain access to land by continuously cultivating it and living in the village. There are very few alternative income opportunities and Paper I points towards a link between landlessness and malnutrition. The households with well-nourished children all have access to agricultural land and some of them cultivate a large number of plots. Paper III illustrates the link between landlessness and nutrition and how landlessness may lead to food insecurity and malnutrition.

5.7.3 The macro socio-economic context of malnutrtion

The DRC socio-economic context

Child nutrition is influenced by several macro-level factors and needs to be understood in the context of socio-political processes at regional, national and international levels. Research has also demonstrated how malnutrition can be related to broader historical, political and ecological factors [145, 171]. Economic growth, governance and political conflicts especially are known to have significant effects on nutrition [173, 174]. Food insecurity and malnutrition in Bwamanda is, as in other rural areas in the DRC, to a large extent related to distal factors including the government being unable to deliver basic services to rural areas such as agricultural support, infrastructure development, health care, access to clean drinking water and education [54]. Institutional decline, economic underdevelopment and exploitation of natural resources in the DRC can be traced back to the thirty years under the government of President Sese Seko Mobutu. This period was marked by a patrimonial state and clientism resulting in a severe decline in the economy and infrastructure as well as institutional deterioration [272]. Since 1996 a number of conflicts have destabilised the country and further restricted the government's ability to promote development, especially in the agricultural sector [180]. Development aid in the DRC has focused on humanitarian assistance to the eastern provinces and paid little attention to productive activities [180]. Since independence, the DRC agricultural policy has emphasised exports of cash crops and this policy has been unfavourable to the development of staple crop production.

The local NGO

As in many other areas in the DRC where public social services are minimal, a local NGO, CDI-Bwamanda, delivers services [180, 273, 274]. Through its office in Bwamanda the organisation has provided agricultural extension, health and educational services to people in the Bwamanda. These activities have been supported by the organisation's office in Kinshasa. International organisations have provided financial assistance to the organisation. During recent years, mainly because of a reduction in financial support from international donor organisations, CDI-Bwamanda has had to reduce its assistance and trim down its activities in Kinshasa. Paper III indicates that service delivery in Bwamanda is unequally distributed. The relatively better-off with well-nourished children have managed to benefit from assistance in areas such as promotion of agricultural activities and provision of safe

drinking water, while poorer households have benefitted less. In addition, health services are difficult to access and expensive, especially for the poor. Research has shown that by scaling up health interventions and achieving better coverage, programmes can succeed in improving equity in nutrition [275]. Accordingly, unequal access to services and social differences in nutrition in Bwamanda is probably related to poor coverage. A further scaling down of NGO services in Bwamanda might therefore lead to increased inequalities in nutrition.

5.7.4 Social inequalities in malnutrition

The literature has linked social determinants of malnutrition to income-related inequalities and documents pro-rich disparities in nutrition [144, 146, 149]. Household income and food prices are also closely related to food security and an inability to access food to be largely determined by a low ability to purchase food rather than by local food production [276, 277]. However, since subsistence agriculture is the major livelihood in rural DRC, food security and inequalities in child nutrition are closely related to people's capacity to produce enough nutritious food [269]. Consequently, differences in nutrition are related to unequal access to crucial resources for agricultural production.

Social field theory can be applied in the analysis of social inequalities in nutrition. Social fields relate to the concept of different forms of capital with capital functioning and existing in relation to social fields [223, 224]. The Ngbaka settled in the area are mainly subsistence producers and labour is a major capital. Labour is associated primarily with two social fields, that is the household and the *gbisa*. Those who have sufficient labour and access to land can convert the capital into food, sufficient in terms of quantity and quality. In this manner the households with enough labour can make sure that their children are well-nourished. Land is also a crucial form of capital and given that the farmers have sufficient labour the agricultural producers with access to fertile land can provide their household members with an adequate diet.

Paper III shows that it is not only economic capital such as land and household labour that is important but also social capital in the form of social networks that can be mobilised for agricultural production and capital accumulation. In Bwamanda the *gbisa* is important for mobilising labour as well as accumulation of capital. Those who participate in *gbisa* can solve seasonal bottlenecks and thereby ensure that their household produces sufficient food.

Farmers can also participate in *gbisa* in order to accumulate capital and further enhance their livelihood. Social networks are also important in order to access social services and good contact with the local NGO people might improve their access to services provided by this organisation.

The material presented here demonstrates the importance of the concept of capital volume and of differences between those with relatively more capital and those without much capital [278]. Those with much economic and social capital have access to nutrient-dense food including animal source foods. They grow a variety of crops, have developed fruit orchards and invested in livestock. On the other hand those without much capital face problems in obtaining sufficient, good quality food including animal source foods. They face shortages of labour and capital, which constrains them from maintaining and diversifying their livelihood activities.

6. Recommendations and conclusions

6.1 Policy implications

The Lancet series on maternal and child nutrition in 2013 underlines the importance of building a strategy towards better child growth and development on an understanding of how immediate, underlying and basic determinants of nutrition can be changed [10]. This recognition has important implications for strategies to improve nutrition and is based on an assumption that changes in a determinant at one level, for example the immediate level, will only have a limited effect on nutrition.

Nutrition-specific interventions are recognised as cost-effective ways to address the problem of malnutrition and nutrition-sensitive interventions are perceived as having significant potential to lead to a significant reduction in child deaths [279]. At the macro level, economic growth and poverty reduction have been found to have a great potential to reduce malnutrition. Improved governance can have significant positive implications for nutrition because it can influence malnutrition through several channels [173].

Paper II finds a relationship between diet and kwashiorkor and the paper suggests that the consumption of food items containing β-carotene and/or preformed vitamin A might protect against the development of kwashiorkor. The diet in Bwamanda is based mainly on maize and cassava and children are at risk of vitamin A deficiency. Vitamin A supplementation is considered to be an effective intervention in children aged 6–59 months [279, 280].

Dietary diversity among the Ngbaka is closely linked to local food production. Efforts to improve children's diet need to happen through further strengthening of food production and stimulating increased production of crops that contain β-carotene including sweet potatoes and papaya. Research has shown that interventions to promote the production and consumption of orange sweet potatoes have helped increase vitamin A intake and reduce vitamin A deficiencies [281].

Paper III points at the importance of addressing food security and in particular issues concerning the social organisation of local food production. In particular, the study highlights targeting households with few resources in the form of labour and land. The study also

stresses the importance of nutritional programmes supporting local neighbourhood cooperation, for example in the forms of *gbisa*, and that such groups can become vehicles for the improved management of resources, better marketing of farm products, the facilitation of technology transfer and improvement of farmer's access to capital.

Paper I emphasises the importance of properly targeting and scheduling nutritional programmes. The study documents that children at very young ages are at high risk of developing malnutrition. Programmes operating in areas where food insecurity is widespread should pay particular attention to households with infants and toddlers. They should also take into consideration that there are important seasonal variations in malnutrition and that children are at high risk of malnutrition before the first harvest and during the rainy season.

In Bwamanda, malnutrition is closely related to a number of macro factors and it is very likely that economic growth including rural development could have a large positive effect on a child's nutritional status. To improve child nutrition there is a need to make financial resources available in order to initiate and scale up food and nutrition security programmes and in this manner reduce social inequalities in nutrition in the area. The literature underlines the importance of promoting small-scale farms in a development strategy that emphasises equity and poverty reduction [92].

6.2 Future research recommendations

This thesis has examined determinants of child malnutrition. These findings need to be further developed and some of the results should be verified by experimental research.

Paper I investigated seasonal variations in the occurrence of child malnutrition. There is a need to better comprehend how seasonal variations in local food production, including crop production, fishing and collection of wild food influence seasonality in malnutrition. Besides examining food production there is a need to grasp how seasonal variations and women's workload affects child care and feeding practices. By studying patterns in weight and length velocity of young children, an understanding of how the seasons influence child growth can be further enhanced. On-going research using the Bwamanda longitudinal study is addressing this research gap [282].

The relationship between food production and malnutrition at a young age could also be further examined. This should include studies on food production and maternal malnutrition and how maternal malnutrition relates to intrauterine growth retardation (IUGR).

Paper II finds that food items containing β-carotene could play a role in the protective pathway of kwashiorkor. Although the paper emphasises the importance of β-carotene, other carotenoids, a mixture of carotenoids or carotenoids in association with other antioxidants may have played a role in the protective pathway of kwashiorkor. The findings should therefore be confirmed in a randomised trial that involves supplementation of food items that contain various carotenoids.

Paper III illustrates how children living in poor households are at high risk of malnutrition. These are households that lack social and economic capital in the form of land and labour. The household study includes a limited number of households and the findings should be verified by a larger study that uses a mixed method approach. There is especially a need to further explore socio-economic characteristics of households with children who suffer from kwashiorkor.

Bwamanda is also undergoing climate change and it is expected that these changes will have a negative impact on nutrition and health. An increase in temperature and changing precipitation patterns are expected to have a negative impact on crop production [283]. Policy-oriented research on how farmers can adapt to climate change in order to ensure food and nutritional security should therefore be promoted.

This thesis describes a linkage between household food production, food consumption and malnutrition. It therefore addresses issues relating to different branches of learning. In this manner it demonstrates the importance of promoting interdisciplinary research to understand the complexity of determinants involved in child malnutrition.

The thesis applied social field theory in a multilevel analysis that demonstrates how social entities have implications for child nutrition. This approach could be extended to other studies that investigate health outcomes other than malnutrition.

6.3 Conclusions

This thesis investigated how seasonal, demographic, dietary and socio-economic factors influence moderate and severe child malnutrition in Bwamanda. Seasonal variations are found and the incidence of moderate clinical malnutrition (McM) is highest in the pre-harvest period, whereas other forms of malnutrition are high in the rainy season. Age influences the occurrence of child malnutrition and children below 24 months are at a particularly high risk of malnutrition, with risk declining after this age. Findings concerning gender and the incidence of malnutrition are inconclusive. Incidence of malnutrition is highest in girls for some forms of malnutrition whereas for other forms it is highest in boys. Food shortage and monotonous diet is a determinant of severe malnutrition and the study suggests that the risk of developing kwashiorkor increases the longer children consume a diet that excludes food items that contained β-carotene. The study finds that socio-economic factors have consequences for children's nutritional status and generate social inequalities in nutrition. Households with access to vital resources for food production including labour, land, capital and social services could ensure that their children could stay well-nourished whereas children living in households with limited access to these resources are at risk of malnutrition.

The thesis adopted a conceptual framework on malnutrition to analyse determinants that influence child malnutrition in Bwamanda. Factors at three levels were analysed including immediate, underlying and basic level. The study also used social field theory in a multi-level analysis that demonstrates how different social entities have implications for nutrition.

At the immediate level the thesis demonstrates links between inadequate diet and the development of kwashiorkor. From its early description in the literature the development of kwashiorkor in children has been related to an inadequate diet. A number of scholars have investigated the relationship between diet and the development of the disease without being able to identify the dietary factors that determine the development of kwashiorkor. This study finds that, in young children who were chronically malnourished, the consumption of sweet potatoes, papaya and what has been termed "other vegetables" reduces the risk of developing kwashiorkor. These food items contain β-carotene and it is proposed that β-carotene may play an important role in the protective pathway of kwashiorkor. This study is therefore probably the first observational longitudinal study that demonstrates a relationship between

diet diversity and the development of kwashiorkor. The findings should be considered as supportive to on-going efforts that aim at promoting a diverse agricultural and horticultural production and in this manner the stimulation of the consumption of a more varied diet. In rural communities where there is a shortage of vitamin A-rich food it is particularly important to promote increased production of vegetables and fruits rich in carotenoids including sweet potatoes and papaya. The findings should be confirmed in a randomised trial that involves supplementation of food items that contain various carotenoids.

At the underlying level this thesis emphasises the importance of food insecurity and how social organisation of local food production relates to children's nutritional status. As in many other parts of rural DRC, subsistence farming is the major livelihood in Bwamanda and food security relates directly to local food production. Land and labour are important economic resources and access to land and sufficient labour is a pre-condition for ensuring that households have access to sufficient nutrient-dense food for their members. Child malnutrition is also related to the problem of transitory food insecurity.

This study shows that there are seasonal variations and McM can be linked to agricultural season and seasonal stress. The subsistence farmers face food shortages at the end of the dry season. In addition to seasonal stress related to agricultural seasons, child malnutrition can be associated with seasonal variations in disease patterns.

The findings of the study demonstrate the importance of understanding inequalities in nutrition. Children living in poorer household are at high risk of developing child malnutrition. These are households that have a shortage of economic capital as well as social capital. Economic capital is closely linked to social capital and social capital is a precondition to exploit the opportunities that exist in the local community and beyond.

This thesis underlines the importance of understanding how processes at the micro level are influenced by processes at the macro level. The DRC has a long history of internal conflict and political violence constraining the national and local government's capability to promote development in areas such as food production and nutrition. Food insecurity and malnutrition in Bwamanda is, as in other rural areas in the DRC, to a large extent, related to distal factors including the government being unable to provide basic services.

This thesis used social field theory to identify social entities with implications for nutrition. It shows how social field theory can be used in order to identify interlinked local social fields that have implications for child nutrition. At the local level, three social fields—the household, the inter-household cooperation *gbisa* and the village—have consequences for nutrition. These local level fields are again linked to fields at the macro socio-economic level. In this way the analysis shows how events, incidences of malnutrition, at the local level are connected to processes at the macro level. The use of social field theory to understand how determinants at different levels have implications for nutrition could be extended to other studies that investigate health outcomes other than malnutrition.

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Original papers I - III

Corrections

Paper I

Page 1: the article is a research article and not a study protocol

Figure 2: the key is missing and should be the same as in figure 1

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STUDY PROTOCOL

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Incidence and course of child malnutrition according to clinical or anthropometrical assessment: a longitudinal study from rural DR Congo

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Abstract

Background: Longitudinal studies describing incidence and natural course of malnutrition are scarce. Studies defining malnutrition clinically [moderate clinical malnutrition (McM) marasmus, kwashiorkor] rather than anthropometrically are rare. Our aim was to address incidence and course of malnutrition among pre-schoolers and to compare patterns and course of clinically and anthropometrically defined malnutrition.

Methods: Using a historical, longitudinal study from Bwamanda, DR Congo, we studied incidence of clinical versus anthropometrical malnutrition in 5 657 preschool children followed 3-monthly during 15 months.

Results: Incidence rates were highest in the rainy season for all indices except McM. Incidence rates of McM and marasmus tended to be higher for boys than for girls in the dry season. Malnutrition rates increased from the 0–5 to the 6 – 11 months age category. McM and marasmus had in general a higher incidence at all ages than their anthropometrical counterparts, moderate and severe wasting. Shifts back to normal nutritional status within 3 months were more frequent for clinical than for anthropometrical malnutrition (62.2-80.3% compared to 3.4-66.4.5%). Only a minority of moderately stunted (30.9%) and severely stunted children (3.4%) shifted back to normal status. Alteration from severe to mild malnutrition was more characteristic for anthropometrically than for clinically defined malnutrition.

Conclusions: Our data on age distribution of incidence and course of malnutrition underline the importance of early life intervention to ward off malnutrition. In principle, looking at incidence may yield different findings from those obtained by looking at prevalence, since incidence and prevalence differ approximately differ by a factor "duration". Our findings show the occurrence dynamics of general malnutrition, demonstrating that patterns can differ according to nutritional assessment method. They suggest the importance of applying a mix of clinical and anthropometric methods for assessing malnutrition instead of just one method. Functional validity of characterization of aspects of individual nutritional status by single anthropometric scores or by simple clinical classification remain issues for further investigation.

Keywords: Malnutrition, Marasmus, Kwashiorkor, Wasting, Stunting, Incidence

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Background

While the worldwide prevalence of child malnutrition in the period from 1990 to 2010 declined significantly, there has been only minimal change in sub-Saharan Africa [1]. It is therefore important to improve our understanding of child malnutrition in these settings. Many studies from sub-Saharan Africa have determined the national, regional or local occurrence frequencies of child malnutrition. Typically, these studies provide prevalence rates of low anthropometric scores in population cross-sections as the measure of burden of malnutrition. In contrast, longitudinal studies looking at incidence and natural course of malnutrition are few. Such studies are useful because they allow for a better understanding of season- and age-dependent risks for developing malnutrition. The study of the natural course of malnutrition is considered to be of particular value for nutritional programmes in planning interventions [2]. There are very few such studies and according to Isanaka et al. [3] only one population-based study has been published concerning the duration of untreated malnutrition [4]. Studies defining malnutrition clinically (marasmus, kwashiorkor, moderate clinical malnutrition) rather than anthropometrically are also scarce, despite the fact that anthropometric assessment alone lacks specificity in the diagnosis of malnutrition [5].

Given that clinical assessment of malnutrition is a comparatively inexpensive method suitable for regions with a significant burden of malnutrition, the lack of attention to this method is remarkable.

The aim of this paper is to address, in a large population-based study, longitudinal occurrence patterns and course of malnutrition among pre-schoolers and to compare these patterns among clinically and anthropometrically defined malnutrition. Our specific aim was to describe age-, season- and gender- dependent incidence of moderate clinical malnutrition, marasmus and kwashiorkor, and compare these with rates obtained using anthropometrical definitions of malnutrition. We also sought to describe and compare patterns of change and duration of clinically and anthropometrically defined malnutrition.

Methods

The Bwamanda study

This paper presents a secondary analysis of data from the historical Bwamanda study [6]. The rural area of Bwamanda is located in northwest DR Congo and has a tropical climate with the rainy season lasting from April to November and the dry season from December to March. The major livelihood adaptation was subsistence agriculture, mainly cultivation of cassava and maize. The area was served by a central hospital and 10 peripheral health centres with a local NGO that up till today holds the major responsibilities for running the health services in the area. Several health centres had an associated nutritional rehabilitation centre, but the uptake was limited due to time constraints of mothers, the voluntary nature of the personnel services in these centres, and interruptions of stocks of food supplements. During the study sick children were referred to the local health centre or hospital where they received oral rehydration therapy for diarrhoea, antibiotics for severe respiratory infection and chloroquine or quinine for malaria. Moreover, severely malnourished children were offered transport to the Bwamanda hospital. Since the study was undertaken there have been few political and economic changes. The socio-economic development in the area has been constrained by several factors including restricted public service support and only minor private sector growth.

The study included 5 657 children from 16 villages in the Bwamanda area. A sample of 4 238 pre-school children was enrolled at the first contact. During follow-up newborn and immigrated children were added, while some children were lost due to emigration or death. In the last follow up round children who were born in 1984, and had reached six years, were no longer examined. Children were followed in the period 1989–1991. Three-monthly contacts were organised making up 15 months of follow-up and 6 contacts. The area was very homogeneous and there were no significant differences between the villages in nutritional status of the children or socioeconomic status (negligible design effect).

Fifteen interviewers holding a secondary school certificate were trained in simple physical examinations and in undertaking interviews in the villages according to an interviewer's manual. They determined age on the basis of children's birth date noted on road to health charts or/and on parents' identity papers. This information was available for about 90% of the children. For the remaining ones, birth dates were determined by a careful interview of the mothers using a local events calendar.

Nutritional status of children was assessed by clinical assessment as well as by anthropometrical assessment. The clinical assessment of nutritional status is described by Van den Broeck et al. [7]. With this method marasmus was assessed by inspection of abnormal visibility of skeletal structures and by absence or near-absence of palpable gluteus muscle. Kwashiorkor was assessed using the presence of pitting oedema of the ankles and/or feet as a criterion. Moderate clinical malnutrition (McM) was identified as the presence of wasting of the gluteus muscle, wasting at inspection and/or palpation without signs of marasmus or kwashiorkor. Length of children below 12 months was measured with a locally constructed length measuring board, while older children's standing height was measured with a microtoise, in both cases to the nearest 0.1 cm. A spring scale (CMS weighting equipment) was used to weigh the children to the nearest 100 gram. For the present analysis, anthropometric scoring

was done using the WHO-MGRS 2006 Child Growth Standards [8]. Z-scores were calculated for weight for length/height (WHZ) and for length/height for age (HAZ). Children with a WHZ <−2 to >−3 were classified as moderately wasted, those with WHZ <−3 as severely wasted. Similarly, those with a HAZ <−2 to >−3 were categorised moderately stunted and those with HAZ <−3 as severely stunted. Clinical and anthropometric assessments partly take into account different aspects of malnutrition. Both clinical and anthropometric assessments are able to capture wasting processes and are therefore directly comparable methods. However, only anthropometric assessment measures stunting processes.

Incidence rates of malnutrition
Incidence rates of the various forms of clinical and anthropometrical malnutrition were calculated for the age categories 0–5, 6–11, 12–23, 24–35 and 36–71 months. Incident cases were defined as malnutrition being present, but absent at the scheduled previous contact. For the calculation of incidence rates, the person-time at risk was defined on the basis of time elapsed from one contact round to the next, normally about 3 months. Incidence rate was expressed as number per 1 000 person months. Direct age standardization was used to compare incidence rates across seasons by using the age distribution in the first follow up round (second contact) as the reference. Season was defined as: dry post-harvest (January – March); beginning of rainy pre-harvest (April – June); rainy (July – September); end of rainy season post-harvest (October –December).

Natural course of incident malnutrition
To document the natural course of incident malnutrition we examined short-term (3-months) shifts in severity, and short-term (3-months) mortality among children with incident malnutrition. Duration was categorised as 0–3, 3–6, 6–9, 9–12 months, or as censored after end of follow-up. Children with a WHZ and HAZ higher than <−2 were classified as normal, that is "no wasting" and "no stunting".

Ethical aspects
Ethical approval for the Bwamanda study had been granted by the University of Leuven's Tropical Childcare Health Working Group and funding provided by the Flemish Inter-University Council and the Nutricia Research Foundation.

Results
Seasonal, gender and age distribution of malnutrition incidence
Figure 1 shows that incidence rates of marasmus and anthropometric malnutrition were lowest in the dry season and became highest in the rainy season. The incidence rates of McM were highest in the dry season. The rates declined in the middle of the rainy season but increased again at the end of the rainy season. The incidence rates of wasting were particularly high in the rainy season. The rates for moderate stunting were low in the dry season and highest in the rainy season. Severe stunting was low during the dry season and high from the beginning of rainy season to up to the dry season post- harvest. The incidence rate for kwashiorkor was highest in the end of the early rainy season with an incident rate of 1.4 per 1 000 child-months (not shown in figure).

As shown in Table 1, gender differences in incidence of malnutrition varied according to type and severity of malnutrition and according to assessment method. In all seasons there was a tendency for the incidence rate of McM to be higher in boys than in girls, but only significantly higher in the dry season post-harvest [for boys 41.3 4 per 1 000 child-months (95% CI: 35.4, 48.2) vs. for girls 28.74 per 1 000 child-months (95% CI: 23.8, 34.7)].

Figure 1 Seasonality of malnutrition for incidence rates of moderate clinical malnutrition (McM), marasmus, moderate wasting, severe wasting moderate stunting and severe stunting). The incidence rates are given per 1 000 child months. n = 3 620. The numbers for occurrence of kwashiorkor were comparatively too low to be presented. Age is given in months.
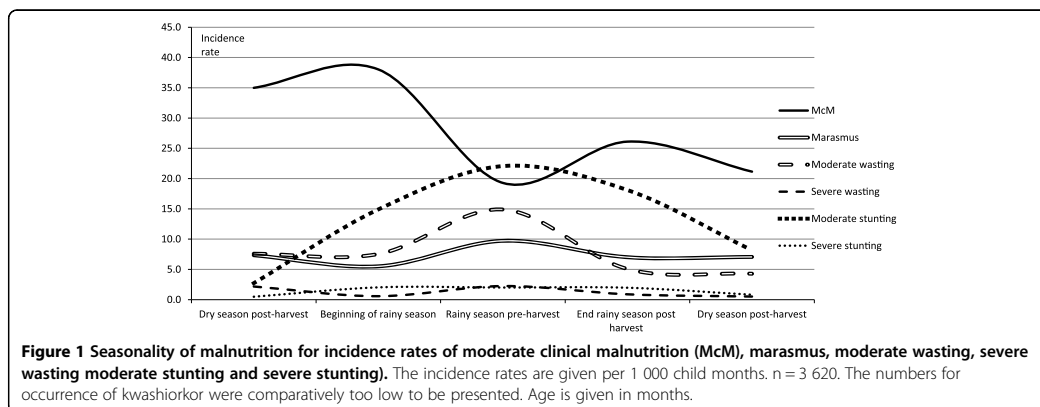
Table 1 Incidence rate by gender and seasons of moderate clinical malnutrition (McM), marasmus, moderate wasting, severe wasting, moderate stunting and severe stunting

	Age standardized incidence rate per 1 000 child-month, (95% CI)							
	Dry season, post-harvest		Beginning rain, pre-harvest		Rainy season		End of rainy season, post-harvest	
	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys
Clinical malnutrition								
McM[1]	28.7 (23.8, 34.7)	41.3 (35.4, 48.2)*	35.5 (30.1, 41.8)	42.3 (36.3, 49.2)	16.1 (13.1, 19.8)	22.2 (18.7, 26.3)	23.0 (19.8, 26.6)	29.5 (25.9, 33.6)
Marasmus[2]	3.5 (2.0, 6.0)	12.0 (9.0, 16.1)*	3.5 (2.1, 5.9)	7.3 (4.4, 12.3)	9.7 (7.3, 12.8)	8.5 (6.4, 11.4)	6.1 (4.6, 8.1)	7.1 (5.5, 9.2)
Kwashiorkor[3]	0.5	0.0	0	0.2	0.7 (0.3, 1.9)	1.7 (0.9, 3.2)	1.7 (1.0, 2.9)	0.8 (0.4, 1.7)
Anthropometrical malnutrition								
Moderate wasting[4]	7.9 (5.4, 11.4)	5.6 (3.7, 8.6)	6.5 (4.4, 9.6)	9.3 (6.8, 12.8)	9.9 (7.5, 13.1)	14.8 (11.9, 18.5)	5.7 (4.2, 7.6)	6.9 (5.4, 9.0)
Severe wasting[5]	0.3 (0.0, 2.0)	1.6 (0.7, 3.6)	0.4 (0.1, 1.9)	0.6 (0.2, 2.2)	1.5 (0.7, 3.0)	3.1 (1.9, 5.1)	1.0 (0.5, 2.0)	1.1 (0.5, 1.9)
Moderate stunting[6]	32.8 (27.2, 39.7)	27.8 (22.7, 34.0)	16.6 (12.9, 21.4)	13.5 (10.3, 17.7)	22.9 (18.9, 27.7)	21.9 (18.1, 26.5)	22.2 (19.0, 26.0)	15.6 (13.0, 18.7)*
Severe stunting[7]	2.1 (1.0, 4.5)	3.5 (2.0, 6.2)	2.3 (1.2, 4.5)	2.1 (1.0, 4.2)	1.2 (0.5, 3.0)	2.7 (1.6, 4.7)	1.2 (0.6, 2.4)	2.7 (1.8, 4.2)

The incidence rates are given per 1 000 child months. N = 3 620. *Confidence interval non-overlapping with that of girls.
[1]Identified as the presence of wasting of the gluteus muscle at inspection and/or palpation without signs of marasmus or kwashiorkor.
[2]Assessed by inspection of abnormal visibility of skeletal structures and by absence or near-absence of palpable gluteus muscle.
[3]Assessed using the presence of pitting oedema of the ankles and/or feet as a criterion.
[4]Weight-for-length/height Z-score <−2 to >−3.
[5]Weight-for-length/height Z-score <−3.
[6]Length/height-for-age Z-score <−2 to >−3.

In the dry season the incidence rate of marasmus was also significantly higher for boys than for girls [12.0 per 1 000 child-months (95% CI: 9.0, 16.1) in boys 3.5 per 1 000 child-months (95% CI: 2.0, 6.0) in girls]. For anthropometrically defined malnutrition, there was no significant gender inequality in incidence of malnutrition, except for a higher incidence of moderate stunting in girls than in boys in the end of the rainy season, post-harvest [for girls 22.2 per 1 000 child-months (95% CI: 19.0, 26.0) vs. for boys 15.6 per 1 000 child-months (95% CI: 13.0, 18.7)].

Figure 2 shows that the incidence rates of malnutrition increased from the 0–5 to the 6 – 11 months age categories in all seasons. In the 3 older age categories (12 – 23, 24 – 35 and 36–72 months) the rates tended to decline with increasing age, also in all seasons. During the rainy season (Panel C) the age-dependent decrease in incidence of MCM, moderate wasting and marasmus appears 'delayed' until after the age of 36 months. In general, clinical malnutrition (McM and marasmus) had a higher incidence at all ages than their anthropometrical counterpart (moderate and severe wasting). The rates for moderate stunting were higher than any other forms of malnutrition up to the age of 12 months. While moderate stunting incidence is very high at younger ages, it becomes lower at older ages. Severe stunting shows a similar pattern, namely an increase up to the age of 23 months and a decrease after that.
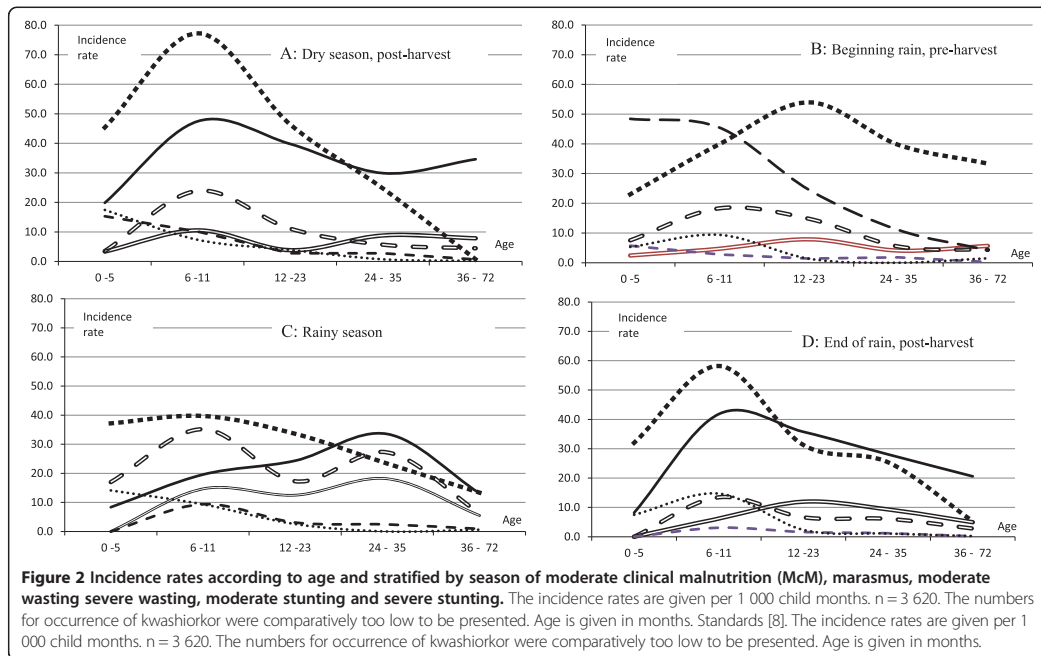
Kwashiorkor was the least frequent type of malnutrition (not shown in Figure 2), with the highest incident rate (2.9 per 1 000 person months) in the rainy season for the age category 24–35 months.

Natural course of incident malnutrition

Table 2 shows that the proportions shifting (3-months shifts) from one level or severity of malnutrition to another differed between clinically malnourished and anthropometrically malnourished children. The percentage of children shifting back to a normal nutritional status within 3 month was higher for clinical malnutrition than for anthropometrical malnutrition (62.2-80.3% compared to 3.4-66.4%). The majority of incident cases normalised after three months, except for stunting where only a minority normalised from moderate (30.9%) or severe stunting (3.4%).

Nutritional status more often remained unchanged in children with moderate forms of wasting (McM and moderate wasting) than in children with severe (severe marasmus and severe wasting) forms of wasting (20.4-25% compared to 9.6-11.5%). As to incident kwashiorkor, 24.3% still presented with kwashiorkor the following round. For stunting, as many as 57.2% of those with moderate forms and 62.5% of those with severe forms had not shifted after 3 months. Alteration from severe to mild forms was more characteristic for anthropometrical than for clinical malnutrition, with the percentage for severe wasting and severe stunting being 27% and 32.1%.

Table 3 describes duration of moderate forms of malnutrition according to season of start of the malnutrition episode. There were no significant differences between McM and moderate wasting. The percentage of McM resolving after 3 months was 64.4% to 76.7% depending on the season, and for moderate wasting 69.2% to 78.3%. Children with moderate stunting resolving after 3 months were a minority (18.4% to 35.3%). A large percentage of

Figure 2 Incidence rates according to age and stratified by season of moderate clinical malnutrition (McM), marasmus, moderate wasting severe wasting, moderate stunting and severe stunting. The incidence rates are given per 1 000 child months. n = 3 620. The numbers for occurrence of kwashiorkor were comparatively too low to be presented. Age is given in months. Standards [8]. The incidence rates are given per 1 000 child months. n = 3 620. The numbers for occurrence of kwashiorkor were comparatively too low to be presented. Age is given in months.

children with moderate stunting remained stunted even after 9 to 12 months.

Discussion

Earlier studies on malnutrition among preschool children have primarily provided prevalence rates of low anthropometric scores in population cross-sections. To our knowledge the current study is among the first to provide incidence rates according to basic determinants and season, and to compare incidence rates of clinically and anthropometrically defined malnutrition. We have shown that seasonal, gender and age distribution as well

Table 2 Shifts in severity of malnutrition after 3 months in children with incident of moderate clinical malnutrition (McM), marasmus, moderate wasting, severe wasting moderate stunting and severe stunting

	Total number of incident cases	Nutritional status after three months % (95% CI)			
		McM	**Marasmus**	**Kwashiorkor**	**Normal clinical status**
McM[1]	1044	20.4 (18.0, 22.8)	2.5 (1.6, 3.4)	0,3	74.3 (71.3, 76.7)
Marasmus[2]	198	5.1 (2.0, 8.2)	9.6 (5.5, 13.7)	1.0	80.3 (74.4, 85.6)
Kwashiorkor[3]	37	0	0	24.3 (10.5, 38.1)	62.2 (44.6, 77.8)
		Moderate wasting	**Severe wasting**		**No wasting**
Moderate wasting[4]	232	25.0 (19.4, 30.6)	4.7 (2.0, 7.4)		66.4 (60.3, 72.5)
Severe wasting[5]	61	27.9 (16.6, 39.2)	11.5 (3.5, 19.5)		52.5 (40.0, 65.0)
		Moderate stunting	**Severe stunting**		**No stunting**
Moderate stunting[6]	687	57.2 (53.5, 60.9)	7.7 (5.7, 9.7)		30.9 (27.4, 34.4)
Severe stunting[7]	557	32.1 (28.2, 36.0)	62.5 (58.5, 66.5)		3.4 (1.9, 4.9)

[1]Identified as the presence of wasting of the gluteus muscle at inspection and/or palpation without signs of marasmus or kwashiorkor.
[2]Assessed by inspection of abnormal visibility of skeletal structures and by absence or near-absence of palpable gluteus muscle.
[3]Assessed using the presence of pitting oedema of the ankles and/or feet as a criterion.
[4]Weight-for-length/height Z-score <−2 to >−3.
[5]Weight-for-length/height Z-score <−3.
[6]Length/height-for-age Z-score <−2 to >−3.
[7]Length/height-for-age Z-score <−3.

Table 3 Duration of incident moderate clinical malnutrition (McM), moderate wasting and moderate stunting

Season at start of malnutrition	Total number of incident cases in the season	Return to normal nutritional status:			
		After 3 months % (95% CI)	After 6 months (%, 95% CI)	After 9 months (%, 95% CI)	After 12 months (%, 95% CI)
		McM[1]			
Dry season, post- harvest	100	76.0 (67.6, 84.4)	19.0 (12.6, 24.2)	2.2	2.0
Dry season, pre-harvest	159	76.7 (70.1, 83.3)	8.2 (3.9, 12.5)	8.8 (4.4, 13.2)	Censored
Rainy season, pre-harvest	174	64.4 (57.3, 71.5)	18.4 (12.6, 24.2)	Censored	
End of rainy season, post-harvest	317	71.0 (66.0, 76.0)	Censored		
		Moderate wasting[2]			
Dry season, post- harvest	26	69.2 (51.5, 86.9)	15.4 (1.5, 29.3)	3.8	0.0
Dry season, pre-harvest	27	70.4 (53.2, 87.6)	22.2 (6.5, 37.9)	No cases	Censored
Rainy season, pre-harvest	60	78.3 (67.9, 88.7)	15.0 (6.0, 24.0)	Censored	
End of rainy season, post-harvest	66	75.8 (65.5, 86.1)	Censored		
		Moderate stunting[3]			
Dry season, post- harvest	68	35.3 (23.9, 46.7)	8.8 (2.1, 15.5)	4.4	10.3 (3.1, 17.5)
Dry season, pre-harvest	52	23.1 (11.6, 34.6)	5.8	13.5 (4.2, 22.5)	Censored
Rainy season, pre-harvest	147	18.4 (12.1, 24.7)	19.0 (12.7, 25.3)	Censored	
End of rainy season, post-harvest	231	32.0 (26.0, 38.0)	Censored		

[1]Identified as the presence of wasting of the gluteus muscle at inspection and/or palpation without signs of marasmus or kwashiorkor.
[2]Weight-for-length/height Z-score <−2 to >−3.
[3]Length/height-for-age Z-score <−2 to >−3.

as course of malnutrition are different when defining malnutrition clinically instead of anthropometrically. For example, we have shown that clinical forms of malnutrition had in general higher incidence rates than their anthropometric counterparts.

The people of Bwamanda are predominantly subsistence farmers and availability of food is strongly influenced by seasonal climatic changes. Our study largely confirmed the findings of other studies showing that the risk of developing malnutrition is especially high in the rainy season [9-11]. We speculate that the high incidence of wasting and stunting in the rainy season could relate to increased morbidity from diarrhoea and malaria whereas the high incidence of McM at the end of the dry season may rather reflect changes in food access depending on the cropping season. Local farmers typically face food shortage during the dry season with a notable shortage prior to the first harvesting of maize in mid-June. However, if we consider age distribution, we found that for the 24–35 months age range the incidence rate of McM was also high in the rainy season.

We found significant gender inequality in the incidence of McM and Marasmus, with the incidence rate being higher for boys than for girls in the dry season. For other forms, both clinically and anthropometrically defined, we did not find that incidence of malnutrition was higher in boys than in girls. However, in one season we found that the incidence of moderate stunting was higher in girls than in boys. There are other studies that have found associations of gender with malnutrition. For example, in a study using data from 16 DHS (Demographic and Health Surveys) in 10 sub-Saharan countries, Wamani et al. found that boys were more frequently stunted than girls [12]. In comparison, in our study incidence of stunting showed no gender difference. Using nine WFS (World Fertility Surveys) and 51 DHS surveys undertaken in Sub-Saharan Africa Garenne et al. examined prevalence of malnutrition and found prevalence of underweight (low weight-for-age) to be higher among boys than girls [13]. We did not examine low weight for age but found that there was no gender difference in incidence of low weight for length/height.

Our study demonstrates that malnutrition incidence at different ages varied according to clinically and anthropometrically defined malnutrition. Still the general pattern for all forms of malnutrition was that incidence was higher at ages 6–36 months than before or after. In a cross sectional study from Uganda Kikafunda et al. found that the risk of older children being stunted relative to younger children were 6 times higher for those in the 12–18 month age range and 10 times higher in the age group above 18 months [14]. While Kikafunda et al. studied prevalence rates, we studied incident rates and found that the risk of developing stunting is high at ages below 12 months and declines at the 12–23 months age range. Our study therefore supports recent studies emphasising the sensitivity of linear growth to environmental factors during the child's early two years of life [15]. In line with this

Victora et al. and Miamady et al., analysing WHO national anthropometric data from 54 countries and Indian National Family Health Survey respectively, found that mean HAZ declined dramatically until at the age of 24 months [16,17]. In Bwamanda weaning food is already introduced at the age of 3 months and this early introduction could explain the high incidence rates of malnutrition in infancy.

We have described the frequency of severity shifts and returns to normal nutritional status after three months. The percentage of children with marasmus or McM who returned to normal was high. It was also noticeable that a large proportion of severely stunted children returned to moderate stunting. Isanaka et al. estimated the duration of untreated acute moderate and severe anthropometrical malnutrition, defined by WHZ and absolute MUAC (mid-upper arm circumference), by a mathematical model and data from a community-based cohort in Niger of children aged 6 to 60 months [3]. Using the 2006 World Health Organization growth standards their study estimated the duration of moderate acute malnutrition to be 2.5-2.7 months (WHZ defined) and 3.4 – 3.9 months (MUAC defined). Isanaka et al. estimated the duration of severe acute malnutrition at 1.5 months (WHZ defined). In our study most of the incident cases of McM and moderate wasting resolved after 0–3 months which suggests that the duration of episodes were more in accordance with the study of Isanaka et al. with regards to moderate malnutrition. The suggested duration of malnutrition was thereby shorter than the duration found in an earlier study by Garrenne et al. [4]. The latter study estimated severe malnutrition (severe wasting) to last 7–8 months on average. We did not have sufficient incident cases in our study to estimate the duration of severe malnutrition with useful precision. Since caretakers were offered assistance this might have influenced the duration of episodes of malnutrition in our study.

Our analysis was based on a large sample of pre-school children, but a weakness is that many children were lost due to emigration and during follow up. This weakness in particular constrained our examination of the duration of malnutrition for severe malnutrition. In order to understand how emigration and lost to follow up might have influenced our findings we compared last nutritional status of children who emigrated or were lost to follow up with children who also were surveyed in the subsequent follow up round. This analysis yielded no evidence that emigration and lost to follow up influenced our findings. Data on incidence and course of malnutrition were obtained from two sequential follow up rounds and thereby dependent on two different measurements. The data on incidence and course of malnutrition were thereby susceptible to measurement errors. We are also aware that we might not have captured some of the shorter episodes of malnutrition which occurred and were resolved between visits.

Conclusions

Our data on age distribution of incidence of malnutrition underlines the importance of strengthening interventions before children reaches the age of 2 years to ward off malnutrition. Our findings, especially with regard to course of McM, marasmus and severely stunted children, emphasise the importance of early life intervention.

There are few population-based studies that have addressed the occurrence dynamics of clinically and anthropometrically defined malnutrition. Our findings show the occurrence dynamics of general malnutrition in a rural African area, demonstrating that patterns can differ according to nutritional assessment method. None of the assessment methods can be described as superior as they partly measure different aspects of malnutrition. Our findings suggest the importance of applying a mix of clinical and anthropometric methods for assessing malnutrition instead of just one method. Functional validity of aspects of characterization of individual nutritional status by single anthropometric scores or simple clinical classifications remain issues for further investigation.

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Diet and kwashiorkor: a prospective study from rural DR Congo

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ABSTRACT

The etiology of kwashiorkor remains enigmatic and longitudinal studies examining potential causes of kwashiorkor are scarce. Using historical, longitudinal study data from the rural area of Bwamanda, Democratic Republic of Congo, we investigated the potential causal association between diet and the development of kwashiorkor in 5 657 preschool children followed 3-monthly during 15 months. We compared dietary risk factors for kwashiorkor with those of marasmus. Kwashiorkor was diagnosed as pitting oedema of the ankles; marasmus as abnormal visibility of skeletal structures and palpable wasting of the gluteus muscle. A 24-h recall was administered 3-monthly to record the consumption of the 41 locally most frequent food items. We specified Hanley–Miettinen smooth-in-time risk models containing potential causal factors, including food items, special meals prepared for the child, breastfeeding, disease status, nutritional status, birth rank, age, season and number of meals. Bayesian Information Criteria identified the most plausible causal model of why some children developed kwashiorkor. In a descriptive analysis of the diet at the last dietary assessment prior to development of kwashiorkor, the diet of children who developed kwashiorkor was characterized by low consumption of sweet potatoes, papaya and "other vegetables" [0.0% , 2.3% (95% CI [0.4, 12.1]) and 2.3% (95% CI [0.4, 12.1])] in comparison with children who did not develop kwashiorkor [6.8% (95% CI [6.4, 7.2]), 15.5% (95% CI [15, 16.1]) and 15.1% (95% CI [14.6, 15.7])] or children who developed marasmus [4.5% (95% CI [2.6, 7.5]) 11.8% (95% CI [8.5, 16.0]) and 17.6% (95% CI [13.7, 22.5])]. Sweet potatoes and papayas have high β-carotene content and so may some of "the other vegetables". We found that a risk model containing an age function, length/height-for age Z-score, consumption of sweet potatoes, papaya or other vegetables, duration of this consumption and its interaction term, was the most plausible model. Among children aged 10–42 months, the risk of developing kwashiorkor increased with longer non-consumption of these foods. The analysis was repeated with only children who developed marasmus as the reference series, yielding similar results. Our study supports that β-carotene may play an important role in the protection against kwashiorkor development.

INTRODUCTION

Malnutrition contributes significantly to the high under-five year mortality in the world and as an underlying factor it has been estimated that it contributes to over one third of all child deaths (*Lim, 2012*). Mortality is very high among children with marasmus, and even higher among those with kwashiorkor (*Briend, Wojtyniak & Rowland, 1987*; *Prudhon et al., 1997*). Kwashiorkor and marasmus are characterised by different metabolic response to severe undernutrition (*Badaloo et al., 2006*; *Jahoor et al., 2008*).

Kwashiorkor has been linked to diet since its first description. *Williams (1935)*, who introduced the name kwashiorkor, suggested protein undernutrition as the etiology of kwashiorkor. The association of kwashiorkor with low protein intake has later been questioned. So far no research has demonstrated that children with kwashiorkor consume less protein than children with marasmus. *Golden & Ramdath (1987)* proposed excess free radicals as the explanation of clinical findings in kwashiorkor. Relations between antioxidant depletion and the occurrence of kwashiorkor have been investigated, but the role of oxidative stress as primary cause of kwashiorkor is still debated (*Ciliberto et al., 2005*; *Lenhartz et al., 1998*; *Manary, Leeuwenburgh & Heinecke, 2000*). We would like to remark that there are difficulties with the oxidative hypothesis. As an example oxidative stress is present in HIV but studies have found oedematous malnutrition to occur in a minority among HIV seropositive patients who are severely malnourished (*Asafo-Agyei, Antwi & Nguah, 2013*).

To our knowledge there are only two observational longitudinal studies that have examined the relations between diet diversity and kwashiorkor. Investigating protein-calorie malnutrition, a study following Indian children from birth to 3 years examined differences in diet between children developing kwashiorkor and children developing marasmus (*Gopalan, 1992*). A more recent study examined dietary factors determining kwashiorkor by assessing diet of one to three years old Malawian children (*Lin et al., 2007*). The former study did not find significant differences in diet between children who developed kwashiorkor and those who developed marasmus, while the latter did not find differences between those who developed kwashiorkor and those who did not (*Gopalan, 1992*; *Lin et al., 2007*).

The overall aim of our study is to investigate, in a large longitudinal population-based study, the possible association between diet and the development of kwashiorkor. We also wanted to compare the causal influence of dietary risk factors for kwashiorkor with those of marasmus. We performed this analysis by applying the causal investigation method proposed by Miettinen and the statistical approach by Hanley and Miettinen, using a random sample of person moments from the entire dynamic population as the reference series (*Hanley & Miettinen, 2009*; *Miettinen, 2010*).

METHOD

The Bwamanda study

We did a secondary analysis of the historical data from the Bwamanda study, conducted from 1989 to 1991 in a rural area of the northwest part of the Democratic Republic

of Congo, (DRC), located at 19.2 degrees east and 3.2 degrees north. The people of Bwamanda are, up till today, predominantly subsistence farmers and the basic diet consists of mainly of maize, cassava supplemented with fish, vegetables and fruits. Health care in the area is provided by a central hospital and 10 minor health centres with a few of these providing some limited nutritional rehabilitation services. With virtually unchanged living conditions in the study area, the secondary analysis was viewed to be contemporary and relevant.

Study design

The Bwamanda study was a dynamic population study with follow-up including thrice-monthly survey rounds, making up 15 months of follow-up and 6 contacts. At the first round 4 235 preschool children were enrolled and at the last round a total of 5 657 were enrolled. A full description of the study population can be found in *Van den Broeck, Eeckels & Vuylsteke (1993)*. Trained interviewers conducted interviews according to an interviewer's manual. They determined the children's age on the basis of birth date noted on children's road to health chart or on parents' identity paper or on the basis of an interview using a local events calendar.

Children were examined for kwashiorkor by using the presence of pitting oedema of the feet or ankles as a criterion. All children were examined for marasmus through inspection of abnormal visibility of skeletal structures and by absence or near-absence of palpable gluteus muscle. A locally constructed measuring board was used for measuring the length of children below 24 months, while a microtoise was used for measuring children older than 24 months. In both cases length was measured to the nearest 0.1 cm. A spring scale (CMS weighting equipment) was used to weigh the children to the nearest 100 g. We applied the WHO Child Growth Standard for anthropometric scoring (*World Health Organization, 2006*). Z-scores were calculated for weight for length/height (WHZ) and for length/height for age (HAZ).

At each contact interviewers undertook face-to-face interviews with the most proximal caregiver of the child, usually the biological mother. The questionnaire included a single non-quantitative 24-h recall with the 41 locally most consumed food items listed and interviewees providing "yes or no" answers to the questions if children had consumed the listed food items during the previous day. The food items had been identified through a pilot study. The interviewees were also asked about number of meals prepared for the families, special meals prepared for the child and breastfeeding.

Statistical method

In an initial descriptive analysis, we tabulated the percentage (95% confidence interval) of individuals eating the different items, grouped by those who developed kwashiorkor, those who did not and those who developed marasmus. We used a two-sample test for equality of proportions to test if the fractions were different.

Here, we were interested in estimation of risks of developing kwashiorkor specific to age, diet, frequency of food consumption, and infectious diseases. We were also interested in the duration of a particular diet; did a child eat a food item at each visit occurring

every three months over the last 15 months, or only at, for example, one of the interview rounds prior to developing kwashiorkor. Smooth-in-time hazard functions as proposed by Hanley and Miettinen allow this type of analysis (*Hanley & Miettinen, 2009*). We specified Hanley–Miettinen smooth-in-time risk models containing all potential causal factors, including food items, special meals prepared for the child, breastfeeding, disease status, nutritional status, birth rank, age, season and number of meals. To select a representative sample from the study population we used the method proposed by Miettinen, and used the whole study population as reference series (*Miettinen, 2010*). In the analysis we include all new cases of kwashiorkor, but use a representative sample of the non-cases. With a relatively small number of cases, there is little to be gained by letting the number of non-cases become arbitrarily large, having in mind the computational cost of running the model. Results are reported as log-odds ratios (LOR) and risk reductions. In line with this method we took the dataset to consist of 35 person moments (c) where kwashiorkor was observed as the case series, and a representative sample (b) of the infinite number of person moments that constitute the 46 397 person-months in the study base. We use a (b)/(c)-ratio of 150 assuring variances and covariance have minimal errors (less than 1 percentage) compared to using the entire series.

Age function and age as a risk factor

Given that risk is not changing linearly with age, as seen in Fig. 1, we developed an age variable that accounted for nonlinear change in risk. Such transformations are required when risk does not change linearly with age. Accordingly age was included as an independent variable in the model. Based on visual inspection of how kwashiorkor was distributed according to age, a transformation of the age variable was done:

$$f(\text{age}) = a \exp(-b \text{ Age}) * \exp(-a \exp(-b \text{ Age})). \tag{1}$$

To find the parameters a and b, we optimized Eq. (2) with binomial errors using logistic regression.

$$y = a + b * f(\text{age}). \tag{2}$$

The AIC (Akaike Information criteria Information criteria) was used to compare models. To find the parameters which minimized AIC we used an algorithm combining the golden section search and successive parabolic interpolation, an efficient and automated method to find the best model. Here we used the optimize function in *R* to find the parameters which minimized AIC, resulting in $a = 11.55$, and $b = 0.90$ (*Brent, 1973*).

Other risk factors

The risk factors associated with kwashiorkor were defined in two steps; first we specified a log-linear hazard model with binomial errors where the independent variables were all food types, presence or absence of diarrhoea, and stunting and wasting at last visit. We defined time as the natural logarithm of number of months a person had, or had not, consumed a specific food item. We assumed that the food items reported at a given point in
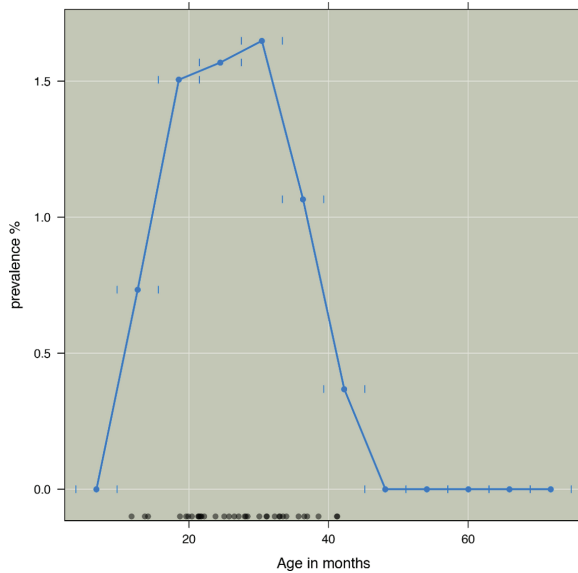
Figure 1 Three months prevalence of kwashiorkor according to age in months in intervals of six months. Prevalence of kwashiorkor (y-axis) against age in months (x-axis). Prevalence aggregated by age group. Short vertical blue lines indicate age groups. Black dots indicate age of those children who developed kwashiorkor. Age at first time a child was observed with kwashiorkor was used.

time were consumed up until the next contact, with the interview during the current visit providing data on any alterations in the consumption patterns since the previous contact.

Each variable was multiplied with the natural logarithm of time the item had been consumed or not. Next, we used the BIC (Bayesian Information Criteria) implemented in *R*'s MASS package (stepAIC) to find the most plausible model based on our data; the posteriori most probable candidate model. The fitted candidate model corresponding to the lowest value of BIC is the candidate model corresponding to the highest Bayesian posterior probability.

Based on the selected model we address the risk of developing kwashiorkor given a prior personal profile. We report risk reduction estimates on the basis of profiles.

To test if the model could also explain the difference between subjects who developed marasmus from those who developed kwashiorkor we applied the final selected model, with the same 35 person moments (c2) where kwashiorkor was observed as the case series, but this time with the references constituted by a sample of the infinite number of person moments including 1 173 person-months observed in 372 new cases of marasmus.

RESULTS

Table 1 reports the distribution of age, the HAZ score and the WHZ score for children with different nutritional status. It shows that children with kwashiorkor were younger

Table 1 Age distribution, length/height-for-age Z-scores (HAZ), and weight-for-length/height Z-score (WHZ) for children with different clinical nutritional status. Z-scores based on the WHO-2006 Child Growth Standards [17].

	Age in month			HAZ			WHZ		
	Q10	Q50	Q90	Q10	Q50	Q90	Q10	Q50	Q90
Kwashiorkor	15.9	26.5	38.4	−4.3	−2.3	−0.8	−2.5	−1.0	0.1
Reference population	7.4	35.9	66.5	−2.9	−1.4	−0.1	−1.4	−0.1	1.2
Marasmus	10.8	28.8	64.0	−4.5	−2.7	−1.2	−2.8	−1.3	0.1

Table 2 Disease status (% of children), sex and age distribution at survey round prior to first observation of kwashiorkor or marasmus. The numbers (n) refer to number of observations.

	Normal $n = 20\,114$	Kwashiorkor $n = 41$	Marasmus $n = 451$
Coughing (%)	35.5 (34.8, 36.1)	34.1 (20.5, 50.7)	43.0 (39.7, 48.5)
Diarrhoea (%)	5.1 (4.8, 5.4)	14.6 (6.1, 29.9)	12.1 (9.4, 15.4)
Anaemia (%)	17.4 (16.9, 18.0)	39.0 (24.6, 55.5)	23.9 (20.3, 27.9)
Fever (%)	10.8 (10.3, 11.2)	15.4 (6.4, 31.2)	16.9 (13.8, 20.5)
Dehydrated (%)	0.4 (0.3, 0.5)	7.3 (1.9, 21.0)	4.9 (3.2, 7.3)
Sex (% male)	51.2 (49.9, 52.5)	47.7 (32.7, 63.1)	60.7 (55.9, 65.3)
Age in months. First round (Q10, Q50, Q90)	6.9, 32.5, 61.1	8.8, 18.1, 29.4	5.3, 24.8, 60.1

than children with no kwashiorkor and marasmus. HAZ and WHZ scores were lower in children with kwashiorkor than in children with no kwashiorkor, but HAZ and WHZ scores were lower in children with marasmus than in children with kwashiorkor. Table 2 shows that the proportion of children with diarrhoea and anaemia was significantly higher in children with kwashiorkor and marasmus than in normal children. The percentage of children that were dehydrated was also highest in children with kwashiorkor and marasmus. In addition the table shows that there were significantly more boys than girls with marasmus.

Table 3 reports the consumption of different food items by the children in the survey round prior to the incidence of kwashiorkor. A high proportion of the children had consumed cassava roots, maize and cassava leaves. The proportion who had consumed cassava roots and maize was non-significantly higher for those who developed kwashiorkor, but for cassava leaves the consumption was lowest for the children with kwashiorkor. The proportion of children who had consumed yam, pineapple, citrus, snails, and eggs was non-significantly higher for the children who developed kwashiorkor than for the others. On the other hand the proportion of children with kwashiorkor who had consumed okra, ground nuts, banana, squash, meat, chili, fish and other vegetables was non-significantly lower than for the rest. There were no significant differences in proportion of children who had consumed palm oil between children who developed kwashiorkor and the

Table 3 Consumption of different food items in the survey round preceding the development of kwashiorkor (n = 37) and non-development of kwashiorkor (n = 8108) and development of marasmus (n = 374) in children between 6 and 50 months of age.

Food items	Children with kwashiorkor % (95% CI)	Children without kwashiorkor % (95% CI)	Children with marasmus % (95% CI)
African pear	0.0 (0.0, 8.2)	0.0 (0.0, 0.1)	0.0 (0.0, 1.3)
Amaranth	7.0 (2.4, 18.6)	1.8 (1.7, 2.1)	3.1 (1.6, 5.8)
Aubergine	0.0 (0.0, 8.2)	0.8 (0.7, 0.9)	0.0 (0.0, 1.3)
Avocado	0.0 (0.0, 8.2)	0.2 (0.1, 0.2)	0.0 (0.0, 1.3)
Banana	9.3 (3.7, 21.6)	19.1 (18.5, 19.7)	16.3 (12.5, 21.0)
Beans	31.1 (30.4, 31.8)	0.4 (0.3, 0.5)	0.0 (0.0, 1.3)
Breadfruit	0.0 (0.0, 8.2)	1.1 (0.9, 1.2)	1.7 (0.7, 4.0)
Cassava leaves	76.7 (62.3, 86.8)	79.2 (78.6, 79.9)	70.7 (65.2, 75.6)
Caterpillars	2.0 (1.8, 2.2)	2.0 (1.8, 2.2)	1.0 (0.4, 3.0)
Cassava roots	76.7 (62.3, 86.8)	72.6 (71.9, 73.3)	72.3 (66.9, 77.2)
Chili pepper	4.7 (1.3, 15.5)	8.9 (8.4, 9.3)	4.5 (2.6, 7.5)
Egg	4.7 (1.3, 15.5)	0.7 (0.5, 0.8)**	1.0 (0.4, 3.0)
Fish	18.6 (9.7, 32.6)	31.1 (30.4, 31.8)	25.3 (20.6, 30.6)
Fruit (others)	0.0 (0.0, 8.2)	1.8 (1.6, 2.0)	1.0 (0.4, 3.0)
Ground nuts	18.6 (9.7, 32.6)	28.6 (27.9, 29.3)	23.9 (19.3, 29.1)
Maize	97.7 (87.9, 99.6)	93.5 (93.1, 93.8)	91.7 (88.0, 94.4)
Mango	0.0 (0.0, 8.2)	0.9 (0.7, 1.0)	0.7 (0.2, 2.5)
Meat	0.0 (0.0, 8.2)	4.7 (4.4, 5.0)	5.5 (3.4, 8.8)
Milk	0.0 (0.0, 8.2)	0.1 (0.1, 0.1)	0.0 (0.0, 1.3)
Mushroom	0.0 (0.0, 8.2)	2.3 (2.1, 2.5)	1.7 (0.7, 4.0)
Okra	2.3 (0.4, 12.1)	4.5 (4.2, 4.8)	5.2 (3.2, 8.4)
Palm oil	86.0 (72.0, 93.4)	88.8 (88.3, 89.3)	80.3 (75.4, 84.5)
Papaya	2.3 (0.4, 12.1)	15.5 (15.0, 16.1)*	11.8 (8.5, 16.0)*
Pineapple	4.7 (1.3, 15.5)	1.4 (1.2, 1.6)	1.7 (0.7, 4.0)
Powder milk	0.0 (0.0, 8.2)	0.0 (0.0, 0.1)	0.0 (0.0, 1.3)
Rice	2.3 (0.4, 12.1)	0.6 (0.5, 0.8)	0.0 (0.0, 1.3)
Sesame	0.0 (0.0, 8.2)	0.1 (0.1, 0.2)	0.3 (0.1, 1.9)
Shrimp	0.0 (0.0, 8.2)	0.1 (0.1, 0.2)	0.0 (0.0, 1.3)
Snails	2.3 (0.4, 12.1)	1.4 (1.3, 1.6)	1.4 (0.5, 3.5)
Soya	4.7 (1.3, 15.5)	5.2 (4.9, 5.5)	5.9 (3.7, 9.2)
Spinach	2.3 (0.4, 12.1)	2.8 (2.6, 3.1)	2.1 (1.0, 4.5)
Squash	0.0 (0.0, 8.2)	4.9 (4.6, 5.2)	5.2 (3.2, 8.4)
Sugar cane	0.0 (0.0, 8.2)	0.7 (0.6, 0.9)	0.3 (0.1, 1.9)
Sweet potato	0.0 (0.0, 8.2)	6.8 (6.4, 7.2)	4.5 (2.6, 7.5)
Termites	0.0 (0.0, 8.2)	0.3 (0.3, 0.4)	0.0 (0.0, 1.3)
Tomatoes	0.0 (0.0, 8.2)	1.3 (1.1, 1.5)	0.0 (0.0, 1.3)
Wheat	0.0 (0.0, 8.2)	0.6 (0.5, 0.7)	0.3 (0.1, 1.9)
Other vegetables	2.3 (0.4, 12.1)	15.1 (14.6, 15.7)*	17.6 (13.7, 22.5)**
Yam	2.3 (0.4, 12.1)	1.3 (1.1, 1.4)	0.7 (0.2, 2.5)

Notes.

* denotes p-value <0.05

** denotes p-value <0.01 with the value estimated using 2-sample test for equality of proportions with continuity correction as implemented in the prop test in R.

other children. The diet of children who developed kwashiorkor was characterized by low consumption of sweet potatoes, papaya and "other vegetables" [0.0%, 2.3% (95% CI [0.4, 12.1]) and 2.3% (95% CI [0.4, 12.1])]. In comparison the children who did not develop kwashiorkor had higher consumption of sweet potatoes, papaya and "other vegetables" [6.8% (95% CI [6.4, 7.2]), 15.5% (95% CI [15, 16.1]) and 15.1% (95% CI [14.6, 15.7])]. The children who developed marasmus also had higher consumption of these food items than the children who developed kwashiorkor [4.5% (95% CI [2.6, 7.5]) 11.8% (95% CI [8.5, 16.0]) and 17.6% (95% CI [13.7, 22.5])].

Given that the β-carotene could be the main acting agent in sweet potatoes, papaya and "other vegetables" we constructed a variable, PaSV (papaya, sweet potato and "other vegetables"), which combined all these items, weighted by the β-carotene content of 100 g of each item. The weighting of sweet potatoes equalled 1 and papaya 1/3. The variable "other vegetables" includes taro, taro leaves and wild vegetables. Taro leaves are rich in β-carotene and a study from DRC shows that wild vegetables are also rich in β-carotene (*Termote et al., 2012*). The PaSV variable did not encompass cassava leaves and amaranth. Since we have not been able to determine the more precise content of the other vegetables in our study, we have weighted the "other vegetables" low, with the weighing equal to 1/10. For the construction of smooth-in-time risk models we defined time for this combined variable as for the single food items.

The most probable model based on BIC included age, time, PaSV, and HAZ. The two variables were correlated ($R^2 = 0.50$). As seen in Fig. 1 the risk of developing kwashiorkor was highest in the age interval between 16 and 38 months.

Table 4 shows the coefficients for the non-proportional hazard model with person moments sampled from the entire population. The log-odds for the continuous variable HAZ; LOR -0.8 (CI 95% [-1.1, -0.5]), length/height for age Z-score, describes an increased risk of developing kwashiorkor with lower height for age. Chronic malnourished children on average have a negative HAZ score, hence the negative log-odds. We found the log-odds for the time variable to be LOR 4.7 (CI 95% [3.4, 6.1]), for the combined variable for food items containing β-carotene it was LOR -9.2 (CI 95% [-21.0, -3.1]), for PaSV, and their interaction it was LOR 8.1 (CI 95% [-11.1, -2.1]). These findings must be understood together. A child not consuming the PaSV food items will have PaSV $= 0$, and thus the interaction term is also zero. The risk of developing kwashiorkor therefore increases the longer the child does not consume the PaSV food items. On the other hand, as illustrated in Fig. 2 a child consuming PaSV food items, PaSV >0, will reduce the risk over time. The overall model fit was good with an AIC of 251.3 and a Nagelkerke R^2 index of 0.44.

Table 5 shows the findings from sampling control-moments only from children who developed marasmus. The table shows that the HAZ score for those who developed marasmus is the same as the HAZ score for the children who developed kwashiorkor (LOR $= 0.0$, CI 95% [-0.1, 0.2]). Then again it shows that there is a difference with regards to consumption of products containing β-carotene with the LOR for PaSV being -6.8 (CI 95% [-17.8, -1.7]) and for PaSV combined with the time variable T the LOR was -6.3 (CI 95% [-9.0, -0.8]). The age of children who developed kwashiorkor was also different

Table 4 **The coefficients for the non-proportional hazard model with person moments sampled from the entire population.** The age variable is a transformation based on the distribution of kwashiorkor across age. T is a variable that describes the duration of consuming a food item containing β-carotene. PaSV is a variable that combines papaya, "other vegetables" and sweet potatoes and weighted by the β-carotene content of 100 g of the item. The height-for-age Z-scores (HAZ) are based on the WHO-2006 Child Growth Standards [17].

Term	Log odds—estimate	Confidence interval, 95%
Intercept	-15.5	$-18.1, -13.4$
Age function of age (months)	10.1	6.1, 14.8
T months	4.7	3.4 , 6.1
PaSV	-9.2	$-21.0, -3.1$
HAZ	-0.8	$-1.1, -0.5$
$T * PaSV$	-8.1	$-11.1, -2.1$
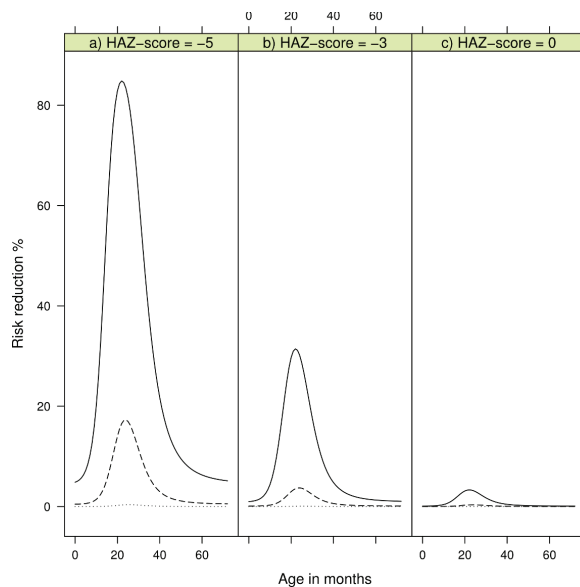
Figure 2 **Risk reduction for developing kwashiorkor showing reduction of consuming β-carotene rich products according to age in months.** The dotted line is risk reduction after two months, dashed line after four months, and solid line after six months. (A) shows risk reduction for a child with a height-for-age Z-score (HAZ) of minus five, (B) for a child with HAZ of minus three, and (C) a child with HAZ of zero. HAZ-scores are based on the WHO-2006 Child Growth Standards [17].

Table 5 The coefficients for the non-proportional hazard model with reference person moments drawn from people developing marasmus. The age variable is based on the distribution of kwashiorkor across age. T is a variable that describes the duration of consuming a food item containing β-carotene. PaSV is a variable that includes papaya, "other vegetables" and sweet potatoes weighted by the β-carotene content of 100 g of the item. Height-for-age Z-scores (HAZ) are based on the WHO-2006 Child Growth Standards [17].

Term	Log odds—estimate	Confidence interval, 95%
Intercept	−9.7	−12.1, −7.7
Age function of age (months)	7.9	4.3, 12.1
T months	4.2	3.2, 5.4
PaSV	−6.8	−17.8, −1.7
HAZ	0.0	−0.3, 0.2
T ∗ PaSV	−6.3	−9.0, −0.8

from children who developed marasmus with LOR being 7.9 (CI 95% [4.3, 12.1]). The age of children with marasmus was distributed within the age of 11–64 months, while the age of children with kwashiorkor mainly fell between 16 and 38 months, reaching a top around 26 months.

Ethical approval for the Bwamanda study was granted by the University of Leuven's Tropical Childcare Health Working Group. Community consent was obtained verbally from community leaders, whereas individual verbal consent was obtained from children's caretakers.

DISCUSSION

Our study shows that the children who developed kwashiorkor were mainly stunted children aged 16–38 months. Their diet was characterized by a low or no consumption of sweet potatoes, papaya and "other vegetables". The children who developed marasmus resembled the children who developed kwashiorkor by being stunted. However, the consumption of papaya, sweet potatoes and "other vegetables" were lower among children with kwashiorkor than among marasmic children. Sweet potatoes, papaya and "other vegetables" are characterised by their high β-carotene content. We found that the risk of developing kwashiorkor increased the longer the child did not consume these food items.

We emphasize the importance of β-carotene because it is a substance with significant antioxidant activities. Also, sweet potatoes, papaya and what we have termed "other vegetables" contain several other carotenoids that have antioxidant activities. As a result the various carotenoids, the mixture of carotenoids or carotenoids in association with other antioxidants in these food items can have played important roles in the protective pathway in kwashiorkor.

Children who developed kwashiorkor also consumed palm oil, with the oil being rich in β-carotene. In Bwamanda palm oil is extracted locally and mostly stored in bottles, often being exposed to strong sunlight. Palm oil is used for preparing cassava leaves stew. The oil is mixed with cassava leaves and boiled in a pot for an hour. Studies show that carotenoids are vulnerable to degradation. It is especially their unsaturated structures

that make them sensitive to heat, oxygen and light (*Leskova et al., 2006*). A study from Nigeria on heating of palm oil demonstrated that the amount of β-carotene declined with temperature increase and that the destruction of β-carotene was greater when the oil was heated continuously for 30 min at any given temperature (*Mudambi & Rajagopa, 2006*). Another study on heating red palm oil showed that all trans-β-carotene were almost lost after 20 min (*Fillion & Henry, 1998*). Thus given that local practices expose palm oil to sunlight and long duration cooking it is unlikely that palm oil consumption would have compensated for the lack of provitamin A in the local diet. However we would like to mention that intervention studies with red palm oil have found improved vitamin A status (*Bhaskaram et al., 2003*).

Besides our study there are only two other observational longitudinal studies we know of that examine the relationship between diet and the development of kwashiorkor: the *Gopalan (1992)* study of Indian children up to 10 years and *Lin et al. (2007)* study on Malawian children. While our study analyses diet with reference to a variety of food items, Gopalan's study concentrated on differences in terms of protein-calorie consumption. Gopalan did not find evidence that there were any differences in the protein calorie intake between cases of marasmus and kwashiorkor. The study conducted by *Lin et al. (2007)* actually found that the daily intake of vitamin A equivalents was low among children who developed kwashiorkor, but not significantly lower than in the control group. The diets of the study population in these studies were monotonous and therefore to some extent resembled the diet in Bwamanda. The diet of Indian children was based on rice and millet, while the diet of the Malawian children was corn-based supplemented by small fish. The diet in Bwamanda consisted to a large extent of maize, cassava roots and cassava leaves.

Golden & Ramdath (1987) suggested that kwashiorkor results from oxidative stress and a general deficiency in protective mechanism that could reduce the oxidative damage with most of the protective pathways necessitating micronutrients. Before target specific antibodies have been produced, immune cells generate and release reactive oxygen species (*Strobel, Tinz & Biesalski, 2007*). These oxidative bursts have been shown to be important in the early phase of for example malaria infections. Oxidative burst can lead to haemolysis and cellular dysfunction (*Isaksson et al., 2013*). Since carotenoids can act as important antioxidants our findings support theories that relate kwashiorkor to oxidative stress and the importance of micronutrients in the protective pathways (*Sergio, 1999*; *Strobel, Tinz & Biesalski, 2007*).

A case-control study examined the antioxidant hypotheses by comparing the diet in siblings of children presenting with marasmus and children with kwashiorkor (*Sullivan et al., 2006*). It concluded that siblings of children with kwashiorkor consumed egg and tomatoes less frequently than children with marasmus did. We note that the differences in consumption between the two were minor.

Studies have questioned the hypothesis that antioxidant depletion causes kwashiorkor. In a controlled trial from Malawi, *Ciliberto et al. (2005)* assessed the efficiency of antioxidant supplementation in preventing kwashiorkor in children aged 1–4 years. The intervention arm received antioxidant powder containing riboflavin, vitamin E, selenium

and N-acetylcysteine, while the control arm received a placebo of an identical looking powder. According to *Ciliberto et al. (2005)* the study showed that the supplementation of antioxidant powder did not prevent children from developing kwashiorkor. We noted that the study did not include supplementation of provitamin A and therefore does not address the efficiency of provitamin A in preventing kwashiorkor. The study did not provide baseline data about study participants' diet. The study design does not, therefore, allow for examining how dietary variables might have influenced the treatment with antioxidant powder and the influence of such variables on the development of kwashiorkor.

As far as we know the Bwamanda study is, excepting *Gopalan (1992)* and *Lin et al. (2007)*, the only observational longitudinal study that describes the diet of children who develop kwashiorkor and marasmus. The results from our study support the hypothesis that kwashiorkor is caused by oxidative stress, supporting the role that food containing carotenoids plays in the protective pathway. In Bwamanda the dietary sources of preformed vitamin A are limited and pro-vitamin A carotenoid constitutes a major source of vitamin A. The pro-vitamin A carotenoids including β-carotene, can through cleavage be converted into retinaldehyde (a form of vitamin A). Studies have shown that the bioavailability of provitamin A carotenoids is less than of preformed vitamin A (*de Pee et al., 1995*; *de Pee et al., 1998*). Our study proposes that the consumption of fruits plays a role in reducing the risk of developing kwashiorkor. In comparison with green leafy vegetables and carrots, fruits are also more effective in improving vitamin A status among children (*de Pee et al., 1998*).

Studies have shown that there is a relationship between diet and infection during the development of kwashiorkor and that recurrent infections contributes to hypo-albuminaemia and the development of oedema (*Frood, 1971*; *Whitehead, 1977*). We also know that vitamin A modulates many types of specific and non-specific immune system and those vitamin deficiencies have a negative impact on different types of immunity functions (*Stephensen, 2001*; *Villamor & Fawzi, 2005*). In this manner provitamin A can play a role in reducing the severity of a number of types of infections and we speculate that provitamin A played a role in reducing the risk of developing oedema among chronically malnourished children in Bwamanda.

The strength of our study is that in a large population-based study we have managed to examine the dietary diversity over a long period of children who developed kwashiorkor and marasmus. The study design has also some disadvantages. Given that information on diet was based on 24 h recall we were not able to determine food consumed in between the follow up period. Furthermore, we have limited information on the quantity of food consumed and we are therefore not in a position to determine the amount of pro-vitamin vitamin A consumed by the children. In our analysis we assumed that the food items reported at a given point in time were consumed up to the next survey round. Given that food consumption is characterised by individual variances this assumption represents a weakness. We also realise that our findings require confirmation, preferably in a large randomised trial that examines the development of kwashiorkor in a trial of carotenoids supplementation.

In conclusion, this is the first observational longitudinal study that demonstrates a relationship between diet diversity and the development of kwashiorkor. We have suggested that the consumption of a diet that includes food items containing carotenoids reduces the risk in children aged 10–71 months of developing kwashiorkor. Our findings should be considered as a support to ongoing efforts that aim at promoting a diverse agricultural and horticulture production and in this manner stimulate consumption of a more varied diet. In rural communities where there is a shortage of vitamin A rich food it is in particular important to promote increased production of vegetables and fruits rich in carotenoids including sweet potatoes and papaya.

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ADDITIONAL INFORMATION AND DECLARATIONS

Competing Interests

The authors declare there are no competing interests.

Author Contributions

- Hallgeir Kismul conceived and designed the experiments, performed the experiments, analyzed the data, wrote the paper, prepared figures and/or tables, reviewed drafts of the paper.
- Jan Van den Broeck conceived and designed the experiments, performed the experiments, contributed reagents/materials/analysis tools, reviewed drafts of the paper.
- Torleif Markussen Lunde conceived and designed the experiments, performed the experiments, analyzed the data, prepared figures and/or tables, reviewed drafts of the paper.

Human Ethics

The following information was supplied relating to ethical approvals (i.e., approving body and any reference numbers):
Ethical approval for the Bwamanda study was granted by the University of Leuven's Tropical Childcare Health Working Group.

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RESEARCH **Open Access**

The social context of severe child malnutrition: a qualitative household case study from a rural area of the Democratic Republic of Congo

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Abstract

Introduction: The magnitude of child malnutrition including severe child malnutrition is especially high in the rural areas of the Democratic Republic of Congo (the DRC). The aim of this qualitative study is to describe the social context of malnutrition in a rural part of the DRC and explore how some households succeed in ensuring that their children are well-nourished while others do not.

Methodology: This study is based on participant observation, key informant interviews, group discussions and in-depth interviews with four households with malnourished children and four with well-nourished children. We apply social field theory to link individual child nutritional outcomes to processes at local level and to the wider socio-economic environment.

Findings: We identified four social fields that have implications for food security and child nutritional outcomes: 1) household size and composition which determined vulnerability to child malnutrition, 2) inter-household cooperation in the form of 'gbisa work party' which buffered scarcity of labour in peak seasons and facilitated capital accumulation, 3) the village associated with usufruct rights to land, and 4) the local NGO providing access to agricultural support, clean drinking water and health care.

Conclusions: Households that participated in inter-household cooperation were able to improve food and nutrition security. Children living in households with high pressure on productive members were at danger of food insecurity and malnutrition. Nutrition interventions need to involve local institutions for inter-household cooperation and address the problem of social inequalities in service provision. They should have special focus on households with few resources in the form of land, labour and capital.

Keywords: Malnutrition, Marasmus, Kwashiorkor, Food security, Subsistence agriculture, Social inequality, Social capital, The Democratic Republic of Congo

Introduction

Malnutrition contributes significantly to mortality in children under five years and in 2011 it was estimated that about 45 % of child deaths could be attributed to malnutrition [1]. Marasmus and kwashiorkor are both forms of severe malnutrition and have especially high mortality rates [2, 3]. While Marasmus is characterised by extreme wasting, Kwashiorkor is characterised by oedema and the aetiology of this disease is still uncertain.

Child malnutrition in the form of stunting, wasting, underweight and severe malnutrition has significant implications for healthy human development in terms of motor skills, and cognitive and social development [4–7]. There are several pathways to malnutrition. Poor diet and illness have been identified as immediate factors that contribute to the development of malnutrition, food insecurity has been identified as an intermediate factor, and socio-economic conditions as underlying causes [8]. Growing social inequalities and determinants of health attracted special attention during the last decades [9, 10]. In low and middle-income countries there is evidence of increasing social inequalities in child nutrition with the highest

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rates of malnutrition being found in the poorest segments of the population [11–14]. Urban–rural inequalities in child malnutrition are frequently found with a higher risk among the rural population [15–20]. The factors that affect nutrition in rural and urban areas differ and a higher reliance on agriculture and natural resources, and a lesser dependency on cash income are characteristic of rural areas. [15]. The majority of rural people in low-income countries live on small farms of less than one hectare and agriculture is the foremost provider of food and the principle source of income [21–23]. Sub-Saharan Africa is more dependent on agriculture than any other region in the world and small-scale agriculture is particularly important [24]. In areas that strongly depend on agriculture there is a close linkage between agriculture and nutrition. Agriculture as a source of food is the most direct pathway between agriculture and nutrition [25]. The urban–rural gap in malnutrition has also been attributed to factors such as education, access to quality food and availability of health services [15, 17, 18, 20]. Maternal education, especially education at secondary level, is considered to be among the most important factors that explain urban rural differences in malnutrition [17, 18, 20]. Besides investigating inter-household inequalities, several studies have examined intra-household inequalities in nutrition. While studies from South Asia have reported discrimination against girls in food allocation and malnutrition being more common among girls than boys [26–29], research from sub-Saharan Africa on gender inequalities in nutrition is inconclusive [30–33].

The Democratic Republic of Congo (the DRC) is among the countries in the world with the highest rates of child malnutrition [1, 34]. Although malnutrition is widespread in all provinces there are important geographic variations and the occurrence is significantly higher in rural than in urban areas [34, 35]. While the prevalence of stunting in rural areas in 2013 was 47 % it was 33 % in urban areas. In the rural areas of the DRC subsistence agriculture is the major livelihood for the majority of the households [36, 37]. Currently there are several constraints to subsistence production: farmers cultivate small land-holdings, they rely on traditional cultivation technologies, have limited access to agricultural input, infrastructure is poor and pressure on the productive population is high [35, 36, 38]. In the context of civil war the subsistence agricultural sector has also been seriously neglected by the government and development agencies [37].

In small-scale agricultural communities the household is typically the unit responsible for food production and consumption [39, 40]. Hence, the social organisation of the household has important implications for food and nutritional security [39]. In this paper we explore how household characteristics, access to land and inter-household cooperation affect food security and vulnerability to child malnutrition in an environment where subsistence agriculture is dominant. Using the Bwamanda area, located in a rural part of western DRC as a case, we aim to describe the social context of food production and nutrition, and explore how some households succeed to ensure that their children are well-nourished while others do not.

Methods

Study setting

The Democratic Republic of Congo (the DRC)

The DRC is located in south-west central Africa and is the second largest country in Africa. It is divided into ten provinces and one city province (see Fig. 1 map). In terms of natural resources it is among the richest countries in the world and has a diversity of mineral and forest resources [41]. It also has an environment that is favourable for agricultural activities and allows for two harvests per year [42]. Despite the DRCs wealth in natural resources, its population is among the poorest in the world and because of its poor scores with regards to income, health and education it is ranked as second to last according to the Human Development Index [43]. There is a rural–urban gap in poverty disfavouring rural areas where eight out of ten households are living below the poverty line of 1.25 dollars a day while in urban areas it is less than seven out of ten [41]. Since 1997 and until now the political situation in the country has been characterised by civil wars and corruption. The death toll of the civil war, 1998 – 2004, has been estimated to 3.9 million [44]. The conflicts have restricted the country's ability to promote development and it is still strongly dependent on foreign aid [37, 45].

The Equatorial province

The Equatorial Province where this study was undertaken is situated in the north-west part of the country. The province covers an area of 403.292 km^2, 17 % of the DRC, and is composed of five districts. It has a population of five million. According to a UNDP report from 2009 as much as 94 % of the population was living below the poverty line of 1.25 dollars a day, the province was the poorest in the country [46]. The proportion of children suffering from malnutrition in 2013 was high: 57 % of the children under five years of age were stunted and 7.6 % wasted [34]. With prevalence in 2007 of 10.5 %, this province had the highest proportion of children with kwashiorkor [47].

Bwamanda area

The study was carried out in the Bwamanda area in the north-west of the Equatorial Province. Bwamanda village

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Fig. 1 Map The Democratic Republic of Congo, provinces and location of Bwamanda

and its surrounding villages form the Bwamanda area, with a total population of about 209,000. The Ngbaka is the dominant ethnic group. Their principle livelihood is subsistence agriculture [48–50]. Bwamanda is a large village that has grown into a centre with a marketplace, a hospital and associated health centres. The Bwamanda hospital operates as a first referral hospital for the health district/zone of Bwamanda. Currently, the local NGO, Centre de Développement Intégral Bwamanda (CDI-Bwamanda) is responsible for providing social services in the area.

Data collection

This qualitative study is part of a larger project on malnutrition in the Bwamanda area [49, 51–53]. The data were gathered during three fieldwork visits: October

and November 2012- February- March 2013, and in November 2013. Data collection and translation was done with the assistance of a secondary school teacher teaching English and French. Prior to data collection the first author provided him with a three days training in conducting semi-structured interviewing and organising group discussions. We used purposive sampling of households of two groups based on the criteria of (1) recent history of severe malnutrition and hospitalisation of a child in the household, and (2) absence of a recent history of malnutrition among children in the household.

We met with nurses and physicians working in the hospital and identified four cases of children under-six-years who had been hospitalised for, and later recovered from marasmus and kwashiorkor. With the assistance

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from nurses at health centres, four households with children under-six-year who had not suffered from malnutrition were also selected. During vaccination the health centres had conducted anthropometric assessment and the results had been registered on the children's health cards. The nurses used this information to identify children that had been assessed using normal weight for age charts and found not to be underweight. We had thereby identified eight households in five different villages which were eligible for inclusion in the study. These eight households comprised 12 girls and 17 boys below six years, 24 girls and 11 boys above six years and 24 adult women and 21 men.

Triangulation of data collection methods were applied (see Table 1). Participant observation was used both to map agricultural activities, and the spatial organisation of the villages, and within households to understand household composition, organisation of food production consumption. Semi-structured interviews were conducted with the fathers and mothers of the children as well as other adult household members of all selected households. During the interviews, social factors associated with food production and the children's nutritional status were discussed. To obtain information about socio-economic conditions and social service provision, key informant interviews were conducted with local leaders including the village chief, village secretary, chief assistants and older respected women.

Finally, two focus group discussions were held with male and female leaders to gain a better understanding of the Ngbaka socio-economic organisation including social differentiation. The observation, interviews and focus group discussions were all carried out in the Ngbaka language and translated by the interpreter. All interviews were tape recorded. After each interview the interpreter and the first author went carefully through the tape-recorded interview. The interpreter translated each point raised in the interview orally into English and the first author took notes. The meaning and interpretation of the interview data were then extensively discussed. Field notes from observation and informal conversations were kept in addition to reflection notes from each day of the fieldwork. These served as guides for analysis.

Field theory and data analysis
Field theory
A social field is a domain of social life that has its own rules of organisation and unique characteristics that generate the conditions for the individuals who live in a society [54]. The social fields can be identified in terms of extension in social space, time, number of people and its distinctive characteristics [55, 56]. In the process of identifying social fields the spatial aspect of social fields is in particular important [54, 57]. The fields are interconnected and the theory enables an analysis of how events at the local level are connected to processes at the macro level [56]. The concept of the social field can be used to study the relationship between social factors on different levels that shape food production, consumption and nutritional outcomes. Concretely the theory allowed us to examine how the household as a micro level domain is linked to other social domains and how the dynamics between these domains produce social inequalities in nutritional outcomes. In our field analysis we put emphasise on social organisational aspects of social fields and do not analyse fields as socio-cultural entities with their own forms of communication. We therefore do not analyse meaning and our approach differ from a qualitative content analysis.

Table 1 Number of informants, methods used and dates for interviews and discussions

Informants	Number of informants	Methods	Dates
Informants from households with malnourished children	10	In-depth interviews	February/March 2013
		Participant observation	November 2013
Informants from households with well- nourished children	10	In-depth interviews	February/March 2013
		Participant observation	November 2013
Village leaders	5	Two focus group discussions	February/March 2013
		In-depth interviews	November 2013
Bwamanda hospital and health centre staff	4	In-depth interviews	February/March 2013
			November 2013
Primary and secondary school teachers	3	In depth-interviews	November 2013
CDI Bwamanda representatives	4	In-depth interviews	November/February 2012
			February/March 2013
			November 2013
Total number of informants	36		

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Data analysis

During the field work we observed and discussed with key informants how location related to food production and consumption. We examined this relation with respect to smaller areas including the compound, the neighbourhood, the village and larger areas such as agricultural fields, natural areas in the vicinity of the villages and the Bwamanda area. In this manner with could identify separate bounded areas that we term social space. We identified major characteristics of social activities by describing the context of production and consumption. Making linkages between social space and activities with their own characteristics we could begin to delineate separate fields. Through the description of the household cases we further singled out field characteristics and fields' implications for nutrition. By having identified the social fields we were able to present factors that could be easily compared and analysed. We performed cross case-case comparisons and analysed how the fields had different implications for food security and nutritional status. Household cases were used to show the linkage between social organisation and nutrition and we therefore did not use quotes to highlight this relation.

Ethical issues

Ethical clearance was provided by the Regional Committee for Medical and Health Research Ethics, Western Norway and by the Ethical Committee at the School of Public Health, University of Kinshasa, the Democratic Republic of Congo. For ethical reasons we recruited children who previously had suffered from malnutrition. In regards to the fieldwork and data collection, an information sheet and informed consent form were prepared in the Ngbaka language. We explained the content of the form to each participant and obtained informed consent before starting any data collection including consent to record the interviews. Finally, although the households are described in detail in the findings section, we strived to keep names and location confidential.

Findings

The first section gives an account of the Ngbaka socio-economic organisation and we describe characteristic activities relating to food production, consumption and nutrition. The description of socio-economic context is used as a backdrop for organising the household cases and links between the social context and nutritional outcomes. In the second section eight household cases are presented: the first four are households with a history of severely malnourished children and the last four are those with well-nourished children. Table 2 gives an overview of household cases structured in accordance with the description of the socio-economic context.

Ngbaka socio-economic organisation

Village leadership and access to land

The Ngbaka live in villages whose names typically begins with the pre-fix *bo* which means descendant, followed by the name of the founder of the village. Each village has a chief (*capita*) who is supported by several assistants. Land administration is a major task of the village leadership with the leaders negotiating in land conflicts and being responsible for land redistribution. In Bwamanda, land is under a traditional community-based property system and individual farmers are entitled to usufruct rights. In accordance with the Ngbaka patrilineal descent system land rights are transferred from father to son. In order to uphold usufruct to land the family is required to continuously cultivate it and reside in the village.

Food production

The Ngbaka farmers produce their staple foods through shifting cultivation and a household's planted land commonly covers less than one hectare. Maize and cassava are staples and groundnuts and palm oil are major cash crops. Some farmers also grow crops such as taro, sweet potatoes, pigeon peas, beans and various vegetables and fruits. Farming techniques are very traditional; all operations are done by hand, farmers do not have access to draught animals and fertilisers are unavailable. Agricultural fields are cleared during the first two months of the year, planted and weeded in April up to the beginning of June. The first harvest of maize takes place in June and the other in November, while farmers begin to harvest cassava in October. After three to four years the soil is exhausted and land is left fallow for several years. Fallow land is sometimes used for oil palms and tree crops. To supplement crop production poorer farmers keep poultry and guinea pigs while better-off farmers raise pigs, sheep, goats and cattle.

In addition to agriculture the Ngbaka hunt, gather wild food and fish. Men hunt whereas women gather wild food, but both men and women fish. While men fish using rods, nets and traps, women catch fish in temporarily dammed pools as they drain out. Natural resources in Bwamanda are widely dispersed; agricultural fields can be located up to 4 h walk from the homesteads and in the dry season people go on foot for several hours to fish in the rivers.

Food consumption

The Ngbaka normally eat two meals per day with a main meal that typically consists of *ka,* a stiff porridge made from cassava and maize flour. Porridge is served with a stew of cassava leaves, sometimes enhanced with fish and groundnuts. In between meals, adults and children drink tea with sugar and eat various fruits. Infants are

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Table 2 Overview of social fields with implications for household food security and child nutrition

Case no.	Children's nutritional status	Social fields			
		Household	Gbisa	Village	Local NGO
		Households with malnourished children			
1	Marasmus	Nuclear family	Used male *gbisa* for land clearing	Rights to plots for maize and cassava cultivation.	Marasmic child treated at the hospital
			No use of female *gbisa*	Land redistributed by village chief	No access to safe water
2	Marasmus	Nuclear family	No use of *gbisa*	No agricultural land	Marasmic child treated at the hospital
					No access to safe water
3	Kwashiorkor	Medium sized – extended household	No use of *gbisa*	Rights to agricultural land for maize, cassava and groundnut cultivation	Kwashiorkor child treated at the hospital
					No access to safe water
4	Kwashiorkor	Large extended household – three generations	No use of gbisa	Rights to several plots for maize, cassava and groundnut cultivation	Kwashiorkor child treated at the hospital
					No access to safe water
5	Well-nourished	Medium sized monogamous household	Use of male and female *gbisa* for agricultural activities	Usufruct rights to plots for maize, cassava and groundnut cultivation	Use of health centre services including counselling for infants and toddlers
					Access to safe water provided by CDI-Bwamanda
6	Well-nourished	Large polygamous household – three generations	Use of male and female *gbisa* for agricultural activities	Usufruct rights to several plots for maize, cassava, groundnut and palm oil cultivation	Use of health centre services including counselling for infants and toddlers
			Use of "groundnut" gbisa for capital accumulation investment in bicycle		Access to safe water provided by CDI-Bwamanda
7	Well-nourished	Large polygamous household	Use of *gbisa* for capital accumulation – investment in cattle	Usufruct rights to several plots for maize, cassava, palm oil cultivation and growing fruits	Use of health centre services including counselling for infants and toddlers
					Benefit from project combatting sleeping sickness
					Benefitted from hygiene project
					No access to safe water supply, but involved in planning drilling of new deep water well to be provided by CDI-Bwamanda
8	Well-nourished	Large polygamous household	No use of *gbisa*	Usufruct rights to several plots for maize, cassava, beans and palm oil cultivation	Use of health centre services including counselling for infants and toddlers
			Employ cash labourers and school children as an alternative to *gbisa*		Took advantage of CDI-Bwamanda facilitating transport and sale of maize to Kinshasa
					Benefitted from project combatting sleeping sickness
					Benefitted from hygiene project
					Access to safe water supply provided by CDI-Bwamanda

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predominantly breastfed up to three months old, at which point solid food is introduced to complement breast milk. Breastfeeding normally continues for up to three years. Early complementary food consists of gruel typically made from *ka* and cassava-leaf stew. During meals household members are served the same food, but split into groups; women and young children in one group, older children in another and men in the third.

Labour organisation and inter-household cooperation

Agricultural work is carried out by the household members and has a gender-based division of labour. Men are responsible for clearing land and women do most of the work during weeding and harvesting. Farmers also mobilise labour and capital through the traditional *gbisa*. These are reciprocal groups consisting of close kin and neighbours that are mobilised to solve tasks that the household unit have difficulties solving alone such as land clearing and timely weeding. During *gbisa* the host serves *ka* and cassava leaves and farmers who can afford it serve meat, fish and palm wine. Farmers underline the importance of gbisa and, by organising such groups, they are able to achieve a good harvest and provide household members with sufficient food. Male *gbisa* is also organised for capital accumulation with groundnut *gbisa* being the most common example. In the first year, the person who initiated the group receives an agreed upon number of sacks of groundnuts from group members, and in the following years others obtain sacks of groundnuts on a consecutive basis. Capital from groundnut *gbisa* is typically invested in livestock, bicycles and sewing machines. There is also a second form of *gbisa* for capital accumulation whereby the group establish a revolving fund that provides cash in a sequential manner to its members.

Household organisation

Our study illustrates how households vary in size and composition. There are large multi-generation households and households that are large partly as a result of influx of children from households that have ceased to exist. Other households are large due to polygamy. Small households comprise nuclear families where the sons have broken away from their family and established their own households. The Ngbaka are patrilineal and practice patrilocality, with the wife moving to her husband's father's household after marriage. Local people use wealth to differentiate between households and distinguish three categories—relatively wealthy, average and poor—using the following terms in Ngbaka. The relatively wealthy cultivate a variety of cash crops including palm oil and many have become wealthy through *gbisa*. The averagely wealthy are able to produce enough food for their household members during normal years, while

the poor are not. The poor are also characterised by their limited capacity to participate in *gbisa* as a result of not being capable to provide the food required to host a gbisa and being considered by other farmers as unable.

Service provision

In Bwamanda the NGO, CDI-Bwamanda, has filled the gap in public service provision. Services provided by the NGO include health care, access to safe drinking water and agricultural support. Currently the organisation runs the Bwamanda hospital and associated health centres. In order to improve access to drinking water the NGO has developed a number of deep borehole wells. CDI-Bwamanda has made several efforts to stimulate agricultural growth and provided farmers with improved planting material, facilitated transport of maize for sale in Kinshasa and promoted coffee as a cash crop. A tsetse control program has permitted cattle raising, which was difficult earlier due to trypanosomiasis (sleeping sickness). Due to a decline in financial assistance from international donors over recent years, the organisation has had to scale down its operation and now concentrates on health services. In spite of this CDI-Bwamanda health services are inadequate because of a shortage of qualified staff, basic equipment and essential medicine including ready-to-use therapeutic food to treat child malnutrition. A few years back the hospital received funding for developing local therapeutic food, but funding for this project has ceased.

Case studies

It is in the context of the Ngbaka socio-economic organisation that the household cases must be understood and we have structured the case narratives so that the relationship between the social environment and nutrition becomes more evident. For each case we have therefore described food production, household organisation, inter-household cooperation and household access to social services.

Households with children with a history of marasmus
Case 1

A three-year-old boy was brought to the health centre by his parents in December 2012. He was referred to the hospital, where he was diagnosed with marasmus. Before the child was hospitalised for marasmus the household had insufficient food, and all it could provide the child with was *ka* and cassava leaves. The household comprised five members including the father (29) the mother (28), the boy (3) and twins, 17 months. Another son had died from marasmus a few years back, aged three. The parents of the child first lived with the father's family, but as the household grew larger, they decided to move and find their own place. Following land redistribution

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carried out by the village chief, the couple obtained access to a homestead and agricultural land, with one plot for maize and one for cassava. For clearing the land the father involved a *gbisa*. With their children being so sick, the parents had not been able to spend the necessary time tending to their two plots, and consequently weeds suppressed their fields resulting in poor harvests. Caring for the sick boy and breastfeeding the twins had made it hard for the mother to find time for fishing. Buying fishing hooks was also an unaffordable expense and the father could therefore not go fishing. They failed to produce a sufficient amount of food and had no stores of maize and the family had to subsist on cassava from the fields. Their opportunity to supplement their cassava- and maize-based diet with fish was severely curtailed. Facing acute food scarcity the family had to rely on food provided by relatives living nearby. They also lived on the outskirts of the village and had no access to safe drinking water provided by CDI-Bwamanda.

Case 2

A boy aged 16 months was brought to the health centre in January 2013, where he exhibited signs of severe malnutrition. The health centre referred the boy to the hospital in Bwamanda, where he was diagnosed with marasmus. The family spent one whole day walking to the hospital. In order to pay for the hospital expenses, the boy's mother pledged the only saucepan in the household. Although the boy had not completely recovered he was discharged from the hospital. The health centre in the village continued to provide care for the child until he gradually recuperated. Before the child was hospitalised for marasmus the household had insufficient food, and all it could provide the child with was *ka* and cassava leaves. The household comprised three members; the mother (17), the father (25) and the malnourished boy. In 2011 the family lived in the father's village. They had moved to this village in order to seek patrilineal rights to land. Many years ago the boy's parental grandfather had left this village in order to marry a woman from a village outside the Bwamanda area. Moving back to his village of origin, the father had acquired an agricultural plot from a relative. After the land had been cleared, the relative demanded it back. Without any land, the father started harvesting oil palm fruits on the fallow land of other farmers. He thus acquired a very small income from selling palm oil. His wife also received cassava root and leaves as payment for working as a labourer on another farmer's field. Since the household had no access to land they did not participate in *gbisa*. The household had no stores of grain and they had no relatives who would help them with food. In addition they had no access to safe water provided by CDI-Bwamanda.

Households with children with a history of kwashiorkor
Case 3

A three-year-old boy was brought to the health centre by his parents and the centre referred the boy to the hospital, where he was diagnosed with kwashiorkor. In the period before the boy fell ill from kwashiorkor he had been eating mostly *ka* and cassava leaves. The household was composed of 12 members including the father of the boy (42), his second wife (32), the father's mother, five adolescent girls and four preschool children. Two of the preschool children, including the boy who had suffered from kwashiorkor, were children of the first wife of the father. The first wife had left and given the father the responsibility of taking care of the two children. The household cultivated two plots on which they grew maize and cassava for subsistence, and groundnuts as a cash crop. Because the fertility of the land in use was rapidly declining, the father wanted to clear more fallow land. With only one adult male member, there was inadequate labour within the household to clear additional land. Income from the groundnut sale was spent mostly on school fees for the older children and there was no surplus for hiring labour. Involving the *gbisa* in clearing the land was also said to be impossible because it required the household to provide fish for feeding the group members during the workday. The father said he did not have enough cash to buy fishhooks and could not afford to purchase fish. He and his second wife reported that because they were unable to clear more land they were incapable of providing a more diverse diet for their household members. The household had no access to safe drinking water provided by CDI-Bwamanda, and they fetched water from a reservoir that was also used for washing clothes.

Case 4

An 18-month-old girl was brought to the health centre by her parents in January 2013. She was referred to the hospital where she was diagnosed with kwashiorkor. During the period before she was hospitalised she had suffered from diarrhoea, vomiting and fever. The girl was breastfed complemented with gruel that contained fish. The parents explained that the girl became malnourished because she drank contaminated water from a hand-dug well. The household comprised 30 members from three generations, among them the father of the girl (34), the mother (34), and seven children. They cultivated several plots of land and in addition to producing staple crops for subsistence they obtained cash income from selling maize and groundnuts. They were dependent on household labour, but occasionally hired labour for clearing fallow land. They had also invested in 12 goats used for meat. In addition to *ka* and cassava leaves, they had fish almost every day, as well as chicken

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and other meat a couple of days per week. They had no access to safe drinking water, from CDI-Bwamanda and they collected water from a hand-dug well that was deemed unsafe and several household members had become sick after drinking water from this source.

Households with well-nourished children
Case 5

This was a monogamous household consisting of 15 members in total. The household head lived with his wife and his sister, two adolescents and ten younger children, all relatives. On their land, the household cultivated cassava, maize, groundnuts and beans. Farm work was done by the household members, but labour was also mobilised through participating in male and female *gbisa*. The women prepared *ka* and cassava leaves for *gbisa* and it was not expected for them to provide fish or meat to the members of the work groups. The head was an active fisher and hunter. Around the homestead the household also grew a number of fruit trees. The household emphasised the value of a diverse diet and argued that they gave their children fish and fruit every day. They obtained safe drinking water from a water source prepared by CDI-Bwamanda.

Case 6

In this household, comprising 19 members, the head lived with his three wives. Other relatives in the household included three adult males, one adult female, six adolescents and five younger children. They had managed to clear several agricultural plots for cassava, groundnut and palm oil cultivation. In addition to household labour they relied on mobilising *gbisa* for land clearing and weeding. In the male work group fish and meat was served. The adult males participated in a "groundnut *gbisa*" and they had used the income from the *gbisa* to purchase a bicycle. They produced enough crops and cash to ensure that their members obtained a sufficient diet that usually included fish. In their compound they grew fruits and in between the meals children and adults ate bananas and pineapples. The household lived in the centre of the village and collected water from a borehole well drilled by CDI-Bwamanda.

Case 7

In this household there were 12 members where the livestock keeper lived together with his two wives, three adult males, two adult females, two adolescents and two younger children. The members of the household were all relatives. The household cultivated palm oil and coconuts in addition to the most common crops. It had also established a separate fruit orchard. In order to secure a regular supply of fish, one of the head's wives specialised in fishing. The head participated in a *gbisa* that established a revolving fund providing cash on a consecutive basis to its members for capital accumulation and investment in livestock. To cover the *gbisa* investment, the household head used funds that his wives had saved from selling palm wine. With the capital received from the *gbisa*, the household invested in cattle. The *gbisa* group had later evolved into a group of livestock owners who cooperated on preventing livestock diseases. The adult members reported that their children were well-nourished because they could provide them with a diverse diet that included fish, meat and fruit. They also stated that good hygiene was important. In 2011 a project promoted good personal hygiene in the Bwamanda area and advised the household members to wash their hands before meals. They had attached a water bottle to a tree and water from this bottle was used for hand washing. Because the household had no access to safe drinking water, the head was in regular contact with the CDI-Bwamanda in the planning of drilling a new borehole well.

Case 8

This business household consisted of 13 members and the head lived with his three wives. Other relatives in the household included three adult males, one adult female, two adolescents and two younger children. They cultivated the most common staple crops while coconuts and oil palm were grown as cash crops. Besides employing household labour, they hired farm labourers and also engaged school students during harvest. Previously, CDI-Bwamanda had promoted cash cropping by purchasing crops from local farmers and shipping the produce to Kinshasa. At the beginning of the 1990s the household took advantage of this opportunity and with the profits made on cash crops they invested in a cigarette business. Income from the sale of cigarettes was invested in pigs, sheep and goats and, at a later stage, in cattle. The head believed that his children were healthy because, aside from *ka* and cassava leaves, they ate fish and a variety of fruit. The household had also followed the advice from the hygiene project and used water from a bottle attached to a tree for hand washing. It had access to drinking water from a borehole well drilled by CDI-Bwamanda.

Social field analysis
We have identified four social fields that extend in social space each with their own characteristics. On the basis of our description of the Ngbaka socio-economic context it is possible to make linkages between activities and specific locations. Food production and consumption is associated with the household compound and household agricultural plots, access to external labour and capital with the neighbourhood, acquiring land with the village

and social service provision with local NGO activities which again are linked to activities at the national and international level. Several characteristics are unique to these to these four fields. The household is the major unit for food production and consumption, division of labour is gender based and household composition influences its ability to produce sufficient and adequate food. Neighbourhood cooperation in the form of gbisa is characterised by being a reciprocal group for exchange of labour and provision of food and drinks to participants influence people's willingness to participate in work groups. The gbisa plays and important role in capital accumulation. The village is associated with access to land and land is transferred from father to sons, living in a village and continuously cultivating the land is a precondition for access to land. The local NGO, CDI Bwamanda; in the absence of a strong state has become the main provider of social services. The NGO's provision of social services establishes linkages between local activities and processes at higher levels. The identification of the fours social fields enabled us to conduct a cross-case analysis and compare households with malnourished children with those with well-nourished children.

The household
In our cases there are links between household size, composition and children's nutritional status. Large households comprising many adults with relatively little pressure on productive members were able to broaden their economic activities and supply members with an adequacy of food, both in terms of quantity and variety. For example, household 7 included six adults and had managed to diversify its food production. The members specialised in growing fruit, making wine, herding cattle and fishing. In contrast, as indicated by case 1, nuclear families were particularly vulnerable and, when members became sick, the effect of ill health was food insecurity and malnutrition. It was not only size and dependency ratio that mattered, but also gender composition. The farmers practice shifting cultivation and clearing land relies heavily on male labour. As illustrated in case 3, shortage of male labour can result in failure to clear land, food insecurity and malnutrition. Among the Ngbaka it is women who are mainly responsible for weeding. Household 1 comprised only one woman and the poor harvest was primarily due to failing to properly weed the agricultural fields.

Inter-household cooperation – the Gbisa
Efficient food production does not only rely on household size and composition, but also on inter-household cooperation in the form of participation in gbisa. The cases show how households with well-nourished children managed to solve seasonal bottlenecks by mobilising

agricultural labour through gbisa participation. In case 5, the household was in a positon to supply food desired by the group and by mobilising a work group it could solve the problem of shortage of male labour. In contrast, the household in case 3 was unable to provide the food needed to join a gbisa. The failure to take part in work groups was linked to an incapability to provide an adequate diet and malnutrition. Gbisa was also used for capital accumulation and revenues were used to strengthen household economic activities and thereby enhance food security. As illustrated in case 6, income from groundnut gbisa was spent on improving household transportation, while in case 7 profits were invested in cattle.

The village
In Bwamanda rights to land are closely linked to the village as a unit and access to land is maintained by staying in the village and continuously cultivating the land. In our cases, households with well-nourished children had access to labour and land, with wealthier households cultivating relatively large areas of land. In an area such as Bwamanda where there are few alternative income generating activities landlessness may result in food insecurity and child malnutrition. Household 3 illustrates this link between landlessness and malnutrition. The household which moved to the village of the malnourished child's father failed to obtain agricultural land and had to rely on food as payment for work and a meagre income from selling palm oil.

The local NGO
Our study indicates that access to the limited services that exist is disproportionately associated with wealth. For example, in case 7, the household took advantage of efforts made by CDI-Bwamanda to promote the sale of maize. Profits made on cash cropping were used to expand economic activities with earnings being invested in petty-trade and livestock. The two better-off households (cases 7 and 8), also benefited from efforts to combat sleeping sickness, and as a result of the decline in this disease they could keep cattle. These two households also followed advice given by a hygiene project. Moreover households with well-nourished children gained from CDI-Bwamanda's endeavours to improve access to safe drinking water while those with malnourished children had not. In case 4 the parents of the girl with kwashiorkor stated that malnutrition was a result of drinking contaminated water. Several factors constrain a household's access to health services that could treat malnutrition. Local people have no means of transportation and parents must walk long distances to reach Bwamanda hospital. As indicated in case 2 it is difficult for poor households to pay fees for healthcare and the

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poor family had to sell their assets to cover hospital fees for treating the boy with marasmus. Bwamanda hospital also lacked food to properly treat malnutrition and the boy did not recover after he had been treated at the hospital.

Discussion

In our study, access to vital resources for adequate food production was related to four social fields that generated conditions for social inequalities in nutrition. Households with sufficient land, enough labour and access to social services could ensure that their children stayed well-nourished. Households with well-nourished children also benefited from taking part in inter-household cooperation. In this study we identified four social fields that had consequences for food security and children's nutritional status. First, household size and composition determined the household's access to labour and hence ability to diversify food production. Second, through neighbour cooperation, in the form of *gbisa*, kin and neighbours could be mobilised for overcoming seasonal bottlenecks and for capital accumulation. Third, the village, which controlled access to land for food production and fourth, the local NGO providing different access to social services including agricultural support and health.

The household

This study has shown how household organisation may relate to food and nutritional security. The Ngbaka live and work in an environment where resources are widely dispersed. In Bwamanda there are hardly any local means of transportation and farmers walk for several hours to reach their farms and fishing grounds. They also practice an intensive form of shifting cultivation. In accordance with the literature, our study demonstrates how in such environments larger households might be more efficient than small [58, 59]. Our findings also support the suggestion that in societies where the household is the production unit, households with a high pressure on the productive members are at risk of not being able to support themselves [60, 61]. Studies have investigated the relationship between family size and malnutrition and found that the odds for being malnourished are higher in large crowded families than in small families [62–65]. Whereas these studies relate family size to household crowding, our study has investigated how household size and composition influences productive activities. Our findings align with the notion that gender division of labour in agriculture has important implications for food production and nutrition [39, 66].

Inter-household cooperation - the Gbisa

In accordance with reports from other areas our cases show that reciprocal work groups can play an important role in mobilising agricultural labour and solving seasonal bottlenecks [67–70]. Our findings show how the working groups could be mobilised in order to solve such tasks as land clearing and timely weeding. In order to mobilise reciprocal work groups, some reward is required - often food or alcoholic drinks [69]. This study shows how being unable to serve food required by the group members limit farmers ability to participate in *gbisa* and how this negatively affects access to labour, food production and hence food security. Reciprocal groups can also be organised for other purposes [71]. Among the Ngbaka such groups can play a role in capital accumulation and enhancement of food security.

Research has dealt with the relationship between access to social networks and children's nutritional status and has found that participation, especially in large networks, is positively associated with child nutrition [72, 73]. Whereas these studies deal with how social networks can enhance mothers' access to health advice, our study shows how networks in the form of inter-household cooperation may facilitate households' access to agricultural labour and capital.

The village

Our findings are in line with the literature that consider access to productive land to be one of the most important factors determining household food security and the landless to be vulnerable to food insecurity [74–76]. Land availability is considered to be a problem in the DRC and although there is a great potential to cultivate land in the DRC, farmers report difficulties in accessing land [36]. Quantitative studies have also found that access to agriculture land plays a role in determining children's nutritional status and that children of agricultural workers are more likely to be malnourished than those of land owners [77, 78].

The local NGO

As in many other areas in the DRC where public social services are minimal, an NGO delivers services in Bwamanda [37, 79, 80]. Our study indicates that the well-off had better access than the poor to the limited services that existed. Food insecurity and malnutrition is, as in other rural areas in the DRC, to a large extent related to distal factors including the government being unable to deliver basic services to rural areas such as agricultural support, infrastructure development, health, access to clean drinking water and education [35]. Other scholars have also demonstrated how macro-relations determine the development of severe child malnutrition. For example, an ethnographic account from rural Tanzania examined how fluctuations in the world economy, land shortage, population growth, social stratification and marginalisation were among the driving forces behind severe malnutrition [81].

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Social inequality in malnutrition

The literature has linked social determinants of malnutrition to income-related inequalities and documents pro-rich disparities in nutrition [12, 14, 82]. Household income and food prices are also closely related to food security. It has been shown that an inability to access food was largely determined by a low ability to purchase food rather than by local food production [83, 84]. However, since subsistence agriculture is the major livelihood in rural DRC, food security and inequalities in child nutrition is closely related to people's capacity to produce enough nutritious food [36]. Research has identified maternal education, emphasising the importance of education higher than primary school, as one of the main factors that benefit child nutrition [14, 17, 18, 20]. Since many women in the study area were illiterate and few had education above primary level [85] we anticipate that maternal education had limited implications for interhousehold differences in nutrition. Several studies from sub-Saharan Africa have investigated intra-household inequalities in the form of gender differences, but conclusions from these studies are contradictory [30–33]. Our field observations and discussions did not point towards any gender-based discrimination in food allocation and a study from Bwamanda did not find significant differences in nutritional status between girls and boys [51].

Strengths and limitations

Studies on social inequality in malnutrition analyse Demographic and Health Survey (DHS) and Living Standards Measurement Study (LSM) data. Using data from a large number of low and middle-income countries research has been able to investigate the presence of and compared national and regional differences in socio-economic inequalities in malnutrition [15, 82, 86]. DHS and LSM apply a standard questionnaire approach on a set of predetermined variables and proxies for socio-economic status may not be representative for rural areas where people predominantly depend on agriculture [15, 87, 88]. This study has used different qualitative methods to gather open-ended information about a specific rural setting and our analysis has uncovered links between local social organisation and inequalities in nutrition. Our study uses few cases but the findings might be transferable to other population in a similar context in the DRC. The variables that we have identified may be applied in quantitative studies that can create quantitative evidence of the relation between the variables and nutritional outcomes in rural areas similar to Bwamanda. The combination of several methods including participant observation, semi-structured interviews and key informant interviews strengthens our study. By combining these methods we have managed to reveal how household organisation, inter-household cooperation, access to land, capital and social services relate to food security and nutrition. Data collection was carried out during three relatively short field work periods and continuing data collection with longer periods we could probably have gained new insights in social aspects of nutrition. We are well aware that our findings are based on a small sample and the results should be carefully interpreted when applied to other settings in the DRC. We therefore realise that social factors with implications for the development of kwashiorkor are somewhat ambiguous, and if we had included more kwashiorkor cases, the social etiology of this disease may have become clearer. The use of an interpreter and not transcribing the interviews also represent weaknesses of the study.

Conclusions

Resources vital for food productions were associated with four social fields and access to these resources was unequally distributed creating social inequality in nutritional outcomes. Households could, by mobilising local institutions for inter-household cooperation, improve their food security. Children living in households where there was a great pressure on productive members were at risk of food insecurity and at danger of developing malnutrition. It is important that nutritional programmes involve institutions for inter-household cooperation to further improve food security and nutritional outcomes. These initiatives should address the problem of inequalities in service provision and making accessible social services that can improve food security and child nutrition in households with few resources in the form of labour, land and capital.

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Annexes

I. 24 h call longitudinal study

II. Interview guide household case study

III. Ethical Approval University of Kinshasa longitudinal study, the DRC

IV. Ethical approval from Regional Committees for Medical and Health Research Ethics, region west, Norway

V. Ethical Approval University of Kinshasa longitudinal study, the DRC

VI. Information sheet and informed consent form

VII. List of wild fruits and vegetables

ENQUETE NUTRITIONNELLE   date de sevrage:année...86.mois.(....

Allaitement:...1...(1=pas d'allaitement 2=allaitement seul 3=allaitement+autre repas)

allaitement:.......(1=normal 2=quantité insuff. 3=mastite 4=autre problème)

HIER, l'enfant a mangé (2=OUI):

1=ananas	.....	15=escargot	......	29=riz	......
2=avocat	.....	16=feuille manioc..2		30=sucré	......
3=agrumes	.....	17=gombo	......	31=sesame	......
4=aubergines	.....	18=huile palme ...2.		32=safout	......
5=amaranthe		19=igname	......	33=soya	......
6=arachide	.....	20=lait animal	......	34=epinard	......
7=arbre à pain	....	21=lait artificiel...		35=tomate	......
8=banane	.....	22=mangue	......	36=termite	......
9=courge	.....	23=mais	...2.	37=viande	......
10=champignon	.....	24=manioc racine..2.		38=blé	......
11=canne à sucre	.....	25=oeuf	......	39=piment 8	......
12=crevettes	.....	26=papaye	......	439=autre fruit....	
13=chenilles	.....	27=poisson	..2...	440=autre légume...	
14=cajan (pois)	.....	28=patate douce......			

Est-ce que l'enfant accompagne la mère aux champs? ___1___ (1=non 2=oui)

   - nombre de repas familials consommés pendant la journée de hier:__2__
   - nombre de bouillies consommés pendant la journée de hier: _0_
   - nombre de snacks consommés pendant la journée de hier: _0_

Il mange avec aide ? (1=sans aide 2=avec aide): __1__ il a un bol à part? __1__(1=non 2=oui

Quel est le nombre de repas préparés spécialement pour lui seul? _0_

Est-ce que l'enfant est MUTUALISE cette année? _2_ (1=non 2=oui)

CONSEILS NUTRITIONNELS reçus aujourd'hui? _2_ (1=non 2=oui)

MEDICAMENT reçu aujourd'hui: NIV-DAR-ASP-FER-AC.FOL-DEC -(encerclez)

ACHAT du mélange soya/sucre dans les 2 derniers mois?__1___(1=non 2=oui)

II

Interview Guide

In-Depth Interviews and Group Discussions

Household information

The child

When did child become malnourished (marasmus/kwashiorkor)
What were the signs according to the parents

Why did he child get sick?

Was the child diagnosed at the health center?

Was the child referred to Bwamanda hospital, hospitalized and for how long?

Did the child recovered and discharged from the hospital

What other illnesses did the child have prior to developing malnutrition?

Food consumption

Food - Child

For how long was the child breastfed?

Was the child exclusive breastfed?

When did the child start to wean?

What food did the child consume before it became sick from malnutrition?

Where did the child eat?

Was the child feeded differently from other children in the household?

What were the problems the family was facing when feeding the child?

Forced feed on or letting the child eat when it wants to eat?

What food do the mother is good for the child and why?

What food is good for the child?

Household food consumption

How many meals do the household members eat per day?

How are the meals organized and who eats with whom?

What type of food items are eaten during the different meals?

Does the household face any problems supplying the household with appropriate food

Household composition

Who are eating and staying together?

What are the kin relations between the people in the households?

Is the household a polygamous or a monogamous household?

Is the household taking care of members from other households?

Who is the head of the household?

After marriage did the wife settle in the household of the husband's family, or did the husband settle in the household of the wife?

Has the household/family left another and established their own household?

Does the family come from the village that they live in now or from another area/village?

Land and agricultural production

Plots cultivated by the households (size and cultivated by whom?

Soil quality (local terms) productivity, erosion, changes in productivity and causes

Farms inputs, seeds, fertilizers (organic, inorganic) and credit availability

Does the household have access to agricultural support and extension services?

What types of crops does the household cultivate, are the crops intercropped?

Clearing, sowing, weeding, harvesting and storing of different crops and what are gender division of labour in the crop production?

Does farmer practice shifting cultivation and how long does it take before the soil is exhausted?

Please describe the agricultural season.

Which crops are for subsistence and which are for cash?

Are the farms located far away and how long does it take to walk to the farms?

Livestock and forestry

Does the household keep any livestock and what is the purpose of keeping the livestock?

Did the household purchase the livestock and how did it manage to get cash to purchase livestock?

Does the household collect plant and fruits from the forest?

Does any members in the household fish in the rivers? Are the rivers located far away?

Are female and males fishing?

What methods are used for fishing?

Group discussion and discussion with village leaders

How is the village organized, does it have a leadership?

What is the role of the village leadership?

Describe the agricultural season; planting, weeding and harvesting.

How do farmers obtain access to land and how is land typically transferred from one generation to the other?

Are there any off farm activities in the village?

Are there any social differences based on wealth in the villages, and what are the criteria used for distinguishing between different wealth categories?

What are the variations in households' access to food throughout the year?

What services are available in the village, including agricultural support, health services and access to clean water?

Ⅲ

REPUBLIQUE DEMOCRATIQUE DU CONGO
Ministère de l'Enseignement Supérieur, Universitaire et Recherche Scientifique
Université de Kinshasa
ECOLE DE SANTE PUBLIQUE
COMITE D'ETHIQUE   *No d'Approbation: ESP/CE/008./.1.4.*

Kinshasa, le 11 avril 2014

A Monsieur le Prof. Dr MAPATANO MALA ALI
Investigateur Principal
Ecole de Santé Publique
République Démocratique du Congo

Objet : Avis favorable concernant l'étude : « *Évaluation de l'état nutritionnel de l'enfant et déterminants de la malnutrition infantile-Analyse des données historiques de Bwamanda, République Démocratique du Congo* ».

Monsieur l'Investigateur Principal,

Le Comité d'Ethique de l'Ecole de Santé Publique de l'Université de Kinshasa a bien reçu le protocole dont le titre est repris en marge.

Après examen du protocole selon les normes d'éthique nationales sur les études impliquant les êtres humains, le Comité a donné un avis favorable à cette recherche et autorise sa mise en œuvre pour la période allant du 11 avril 2014 au 10 avril 2015.

Veuillez agréer, Monsieur l'Investigateur Principal, l'expression de notre considération distinguée.

Prof. BONGOPASI MOKIE SANGOL
Vice Président du Comité Ethique

IV

To whom it may concern

Date
28.01.2013.

Confirmation;

We hereby confirm that the project "Household food strategies and malnutrition in Bwamanda, DR Congo: A qualitative study" by project leader Jan Van den Broeck, Centre for international health, University of Bergen, Norway, is reviewed and approved by the Regional Committee for Medical and Health Research Ethics, Western-Norway.

Best regards

Anne Berit Kolmannskog
Higher Executive Officer

V

REPUBLIQUE DEMOCRATIQUE DU CONGO
Ministère de l'Enseignement Supérieur, Universitaire et Recherche Scientifique
Université de Kinshasa
ECOLE DE SANTE PUBLIQUE
COMITE D'ETHIQUE   *No d'Approbation: ESP/CE/004/213*

Kinshasa, le 18 janvier 2013

A Monsieur le Prof. Dr MAPATANO MALA ALI
Investigateur Principal
**Ecole de Santé Publique**
République Démocratique du Congo

Concerne : Décision du Comité d'éthique portant sur l'étude intitulée : « *Les stratégies alimentaires des ménages et la malnutrition à Bwamanda, R D Congo : Une étude qualitative* ».

Monsieur l'Investigateur Principal,

Le Comité d'Ethique de l'Ecole de Santé Publique de l'Université de Kinshasa a bien reçu le protocole dont le titre est repris en marge.

Après examen du protocole selon les normes d'éthique nationales sur les études impliquant les êtres humains, le Comité a donné un avis favorable à cette recherche et autorise sa mise en œuvre pour la période allant du 18 janvier 2013 au 17 janvier 2014.

Veuillez agréer, Monsieur l'Investigateur Principal, l'expression de notre considération distinguée.
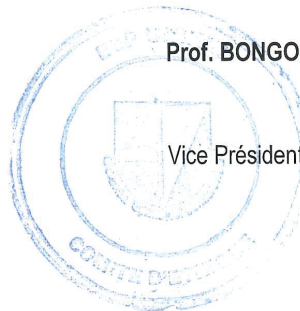
Prof. BONGOPASI MOKE SANGOL

Vice Président du Comité Ethique

Université de Kinshasa Faculté de Médecine : B.P 11850 Kin I.

Informed consent form for local officials, village leaders and villagers invited to take part in the part in the research titled Household food strategies and malnutrition, Bwamanda DR Congo. A

Principle investigator: Hallgeir Kismul; Centre for International Health University of Bergen, Norway

Part I: Information sheet

Introduction

I am working for Centre for International Health, University of Bergen and my study team and I are conducting a research on food and malnutrition. I will give you information and invite you to participate in the research. You do not need to decide now whether or not you will take part in the research. Before you decide you can talk with somebody you feel comfortable whether or not you will take part. This consent form may contain words that you do not understand. When I go through the information please stop me when there is something that you do not understand. I will take time to explain. When questions arise later please ask me.

The purpose of the research

Malnutrition among children is a problem for some households in the community. During the last decades some households have also experienced their children suffering from severe forms of malnutrition. We want to know more about ways to stop this from happening. In consequence we want to find out more about local food production, household's access to food and children's eating habits and health service provision. We also want to learn about parents/caretakers understanding of how children's eating habits are interlinked with children's nutritional status.

Research intervention

This research involves group discussions and individual interviews. The discussions and interviews will last maximum one and half hour. We will take notes so that the answers are written down correctly. We will also use a voice recorder in order to ensure that we catch your answers correctly. An interpreter will be present during discussions/interviews and translate from local language into English.

Participant selection

We have selected you as informant because we feel that your experience as an official/health service provider/village leader/farmer/parent can contribute to improve our understanding of the linkages between food production, eating habits and children's nutritional status in your community.

Benefits and risks

There are no benefits in this study. However, we hope that this study can generate information that can be used in order to further improve the nutritional status of children in this and other communities.

Confidentiality

The information that you give us we will keep strictly confidential and we will not show it to any other persons. The information will not be shared with anyone else than the research team. The data will be kept in the custody of the principal investigator.

Entirely voluntary participation

We like to stress that your participation in the research is entirely voluntary. It is your choice whether to take part or not. If you choose to participate you may change later and stop participating even if you agreed earlier.

Understanding the information given

Please tell us if you do not understand why we are asking you to take part in the research. Please also tell us if you do not understand what our study is about.

Part II: Certificate of consent

I have accurately read the information sheet to the potential participant, and to the best of my ability made sure that the participant understands.

I confirm that the participant was given an opportunity to ask questions about the research, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

Name of research person taking consent:

Signature of researcher taking consent:

Date and place:

Contact information:

For more information regarding this study, please contact the Principal investigator. Mr Hallgeir Kismul, Centre for international health, University of Bergen. Centre for International Health Post-box 7804, N-5020 Bergen Norway, Phone: +47 55 58 85 60 email: hallgeir.kismul@cih.uib.no

Comité d′éthique de la de l'Université de Kinshasa

LISTE DES LEGUMES VEGETAL NATUREL QUE LE TRIBU NGBAKA MANGE.

N° D'ORD	NOMS DES LEGUMES EN NGBAKA.	
01	KAANGA	Feuille
02	NDOMBO	Feuille
03	GBOLO	Feuille
04	LISINGO	-//-
05	SOLE - NGONDA	-//-
06	GBANZIKOTDO	-//-
07	SUMBA	-//-
08	MBULI	-//-
09	BENDE	-//-
10	BAMBALAFOLO	-//-
11	GBAZALA	-//-
12	NDENDE	-//-
13	NKOKO	-//-
14	~~BENDE~~	-//-

	TUBERCULE + FRUIT		10.	ONGO	Fruit
01	LIAN GOLOBU / GBASI		11.	MAKO	-//-
02	LIAN KONZO		12.	ENTA	-//-
03	-//- NDABOA	+ Fruit	13.	TONDE	-//-
04	-//- TUNGULU	+ Fruit	14.	DANBU	KOLA + Fruit
05		KOLE Fruit	15.	NDEA	Fruit
06		KASON -//-	16.	NZIKO	-//-
07		VWUNAU -//-	17.	YOLO	-//-
08		MBOBU -//-	18.	ONGO	-//-
09		BANGOOBE -//-	19.	NGONGO	-//-