Counted – and then
Trends in child mortality within an Ethiopian demographic surveillance site

Anders Emmelin
States Parties shall ensure to the maximum extent possible the survival and development of the child.

Article 6.2, Convention on the Rights of the Child
(In Amharic on back cover)
Abstract

Background

Knowledge of the state of health of a population is necessary for planning for health services for that population. It is a paradox that the health of populations is most commonly measured by mortality and cause of death patterns, but the absence of medical services available to a majority of the world population has made it unavoidable to equate “state of health” with “cause of death pattern”. In the absence of population registration, mortality and causes of death must be studied in samples from the population. The research presented in this thesis mainly has been done within such a sample in a collaborative project between Umeå university and the Addis Ababa university in Ethiopia. This research started 1986 and has run continuously since then. The thesis attempts to measure the effect that social and geographical inequalities has had on the mortality of the children in the study population.

Population and Methods

The population that is included in the demographic surveillance is the children under five years of age in nine rural and one urban community in central Ethiopia. Mortality and causes of death among the children have been followed since 1987.

Results

The mortality of the children in the study is high by international comparisons. The most important reason for mortality differences within the population is the difference in living conditions and societal services between the rural and urban areas. Approximately 45% of the child deaths could have been prevented if living conditions and services had been equal to rural and urban children.

Conclusions

Information concerning mortality and cause of death patterns are essential to planning. In order to empower the population, knowledge of the mortality and most common causes of death must be known to them.
# Glossary

<table>
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<th>Definition</th>
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<tr>
<td><strong>ensete</strong></td>
<td>(Amharic), <em>ensete edulis</em>, “false banana”, indigenous perennial plant with a starchy root/underground stem, staple in the Gurage zone highlands</td>
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<tr>
<td><strong>kebele</strong></td>
<td>(Amharic) Peasants’ Association – the smallest, rural administrative unit of Ethiopian society, PA, also “village”. In the following text, the terms Peasants’ Association (PA), kebele and village are used as synonyms</td>
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<tr>
<td><strong>khat</strong></td>
<td>(Amharic), <em>catha edulis</em>, leafy bush, leaves used as a stimulant drug on the Horn of Africa and Yemen (and in migrant communities in Europe and the USA)</td>
</tr>
<tr>
<td><strong>teff</strong></td>
<td>(Amharic) <em>eragrostis abyssinica</em>, indigenous grain used for staple food, <em>injera</em>, a flat bread</td>
</tr>
<tr>
<td><strong>timad</strong></td>
<td>(Amharic) unit of land area, approximately 0.5 hectares</td>
</tr>
<tr>
<td>verbal autopsy</td>
<td>method for determining cause of death when there is no death registration</td>
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<td>---------------</td>
<td>--------------------------------------------------------------------------</td>
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<tr>
<td><strong>wereda</strong></td>
<td>(Amharic) the administrative unit of district, “municipality”. Is used as synonymous to “district” in the following</td>
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## Abbreviations

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<th>Abbreviation</th>
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<tr>
<td><strong>BRHP</strong></td>
<td>Butajira Rural Health Programme</td>
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<tr>
<td><strong>DSS</strong></td>
<td>Demographic Surveillance System</td>
</tr>
<tr>
<td><strong>PA</strong></td>
<td>Peasants’ Association – the smallest, rural administrative unit of Ethiopian society, kebele or “village” in rural areas</td>
</tr>
<tr>
<td><strong>SNNPR</strong></td>
<td>Southern Nations, Nationalities and Peoples’ Region, one of the regional states that make up the Ethiopian Federation. The region where Butajira is located</td>
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</table>
Original Papers

Paper I  Trends in under-five mortality in rural Ethiopia – 18 years of follow-up in the Butajira demographic surveillance. Anders Emmelin, Mesganaw Fantahun, Yemane Berhane, Peter Byass, Stig Wall (manuscript)


Paper III  Use of biomass fuel is related to indicators of ARI among children under five in Ethiopia. Anders Emmelin, Abera Kumie, Yemane Berhane, Stig Wall, Peter Byass (manuscript)


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Introduction

Up-to-date knowledge of the state of health of a population is well recognised as a prerequisite for planning for services to preserve and improve the health of that population. It seems to be a paradox that the health of populations is most commonly assessed from estimated mortality and cause of death patterns. The absence of medical services available to a majority of the world population has made it unavoidable to equate “burden of disease” with “cause of death pattern”.

In the absence of population registration with reliable and continuous recording of vital events in the entire population, two alternative solutions are used, cross-sectional surveys and sample registration systems that follow a sample population longitudinally through demographic surveillance. The most common of the two is the first type, as represented by the Demographic and Health Surveys that are done at regular intervals in many developing countries (Measure DHS, Macro Int). The alternative, the demographic surveillance system (DSS) as promoted by the international network of demographic and health surveillance sites, INDEPTH (INDEPTH 2009). INDEPTH currently has 34 member surveillance sites in 23 countries, 18 in Africa. The material for this thesis comes from the Ethiopian DSS in Butajira, which is one of the older sites and a founder member of the INDEPTH network.

International child mortality data have been a focus of interest in the discussion of the UN Millennium Development Goals specifically Goal 4, “Reduce child mortality”. Goal 4 has as the first target to reduce the under-five mortality in the world by two thirds between 1990 and 2015. In the World Health Report 2005, under-five mortality in Ethiopia is reported to be decreasing by 1.2 – 1.7 percent annually in the fourteen year period 1990-2003. The report is based on the national Ethiopian DHS survey 2000. The estimated infant mortality rate is 97/1,000 live births in the period 1996-2000 (World Health Organisation 2005). In the report from the 2005 Ethiopian Demographic and Health Survey (Central Statistical Agency (Ethiopia) and ORC Macro. 2006), infant mortality in Ethiopia as a whole is reported to have come down in the last fifteen years (i.e. since 1990) by 19 percent to 77 deaths per 1,000 live births. Under-five mortality is reported to have been reduced by 25 percent from 166 to 123 deaths per 1,000 live births.

A historical comparison shows that Ethiopia in 1996-2000 has an infant mortality that is at the level where Sweden was around 1900
(Brändström A, Edvinsson S, Rogers J. 2002). The 2005 demographic and health survey reported infant mortality is at the Swedish 1910 level.

In modern history, since the overthrow of its last emperor in 1974, Ethiopia has come to be associated in the media mainly with devastating droughts and famines. Newspaper reports and television documentaries have drawn a picture of a country littered with camel carcases and endless lines of displaced families carrying their starving children or queueing for food in refugee camps. While the reports have been true within their own context of then and there, they have hardly told the truth about Ethiopia. As with all famines, the Ethiopian famines have been products of place, time and politics. In terms of physical geography and biology, Ethiopia is a country that could support its own population, in spite of high population density, deforestation and soil degradation.

Ethiopia is one of the poorest countries in the world. Its economy is mainly agricultural, the main exports coffee, hides and leather
products. Agriculture accounts for nearly half of the gross domestic product (CIA.2009). Much of the agriculture is rain-fed and prone to crop failure following drought or untimely rain. Under Ethiopia’s constitution, the state owns all land and provides long-term leases to the tenants who are mainly subsistence farmers. Approximately two thirds of the country is classified as non-food secure for January to March, 2009 (FEWS Net Ethiopia 2009). In spite of a series of five relatively good harvest seasons, Ethiopia is expected to need substantial food aid in the first six months of 2009.

An important question is how an agriculture as rain dependent as the Ethiopian currently is will react to the expected climate changes, which would be expected to create more of extreme weather situations.
OBJECTIVES

Objectives

Overall objective:

To assess the potentials for contributing to the health of a specific population of Demographic Surveillance Systems (DSS).

Specific objectives:

- to follow trends of mortality of children under the age of five over the first twenty-one years of the Butajira DSS
- to identify the most important determinants of under-five mortality
- to assess the impact of such determinants over the twenty-one years of follow-up
Setting, population and methods

In the following sections, I use a mixture of “fact” as supported by printed sources and the knowledge that I have gained over a total of more than two years in the field in Butajira. Whenever I know of an external source, I give the reference. Statements that are not clearly connected to a reference, then, are based on my own beliefs. These beliefs have been formed in interviews and other, more informal interaction with Butajira inhabitants and local project workers as well as with Addis Ababa colleagues, and in years of analysing the data from the BRHP.

The research presented in this thesis mainly has been done within the Butajira Rural Health Programme, BRHP. The BRHP is a collaboration between the departments of Public Health in Addis Ababa University and in Umeå University which has been running since the mid-eighties. At the core of the collaboration is a demographic surveillance system that started with a census in late 1986 and since then has run continuously. Core funding 1986-2008 for the surveillance and for a majority of the PhD students within the collaboration has been provided jointly by Sida/SAREC and the Ethiopian Science and Technology Commission. In 2008 exclusive ownership of the project was transferred to the Addis Ababa University which at the same time agreed to shoulder responsibility for the core funding. As of 2009, the collaboration goes into a new phase as the SAREC funding has been discontinued. Core funding for the surveillance is now provided by the Ethiopian Public Health Association and the collaboration is sponsored by the Umeå Centre for Global Health Research.

Over the years, besides providing the demographic and health data from the surveillance, the BRHP has functioned as an infrastructure for population based research projects addressing specific topics. In the twenty-two years of its operation, the surveillance and infrastructure has provided support for more than a dozen PhD theses and some 50 Master of Public Health theses, mainly by Ethiopians (Berhane Y, Wall S, Kebede D et al. 1999) Among the
research projects are the study of indoor air pollution exposure and acute lower respiratory tract infections among children which is partly included in this thesis (Paper IV). Other studies have focused on reproductive health, intimate partner violence, occurrence and management of childhood illnesses, mental health, *Helicobacter pylori* infection, health care financing and methodological issues in demographic and health surveillance such as sampling errors, impact of errors in data, and *verbal autopsy* methods for establishing cause of death. The BRHP also recently hosted a meningitis vaccine trial.

**The setting**

Butajira town is situated approximately 100 kilometres southwest of Addis Ababa, in the Gurage Zone of the Southern Nations, Nationalities and Peoples’ Regional State in south/central Ethiopia (fig. 1), latitude 8.1° N, longitude 38.3°E. Butajira is the administrative centre of the district, or *wereda* in Amharic, up to recently known as the Meskan and Mareko *wereda*, previously Butajira *wereda*. This district was subdivided into 4 Urban Dwellers’ and 82 Peasants’ Associations, known in Amharic as *kebeles*, which each has a certain amount of autonomy under the District administration (Berhane Y, Wall S, Kebede D *et al.*1999; Berhane Y, Byass P.2002). That original Butajira district was the sampling frame for the BRHP demographic surveillance system. Recently, the district has been divided and kebeles regrouped into three new weredas, Butajira Town Wereda, Meskan Wereda and Mareko Wereda and two of the DSS kebeles transferred to a fourth, the Silti Wereda. So far the spatial definition of the DSS sample has been kept unchanged through these changes.

![Figure 2. Location of the Butajira DSS site](image)

The Butajira area lies on the western rim of the Great Rift Valley with the Gurage mountain chain making up the western boundary of
the district. The topography of the district is varied, from the “lowland” plateau at 1,000-2,000 metres above sea level as the eastern half and “highland” areas of the foothills and slopes of the mountains, from 2,000 m up to 3,500 m as the western half. The district covers an estimated area of approximately 800 km² of which the town covers approximately 9 km². The climate is temperate, with daytime temperatures between 15 and 30 degrees Celsius and nighttime temperature below ten degrees during most of the year. The higher altitudes may occasionally have frost at night. The main wet season is usually June-September, with smaller rains typically February-March. The lower parts of the district are drought prone. Average annual rainfall 1987-2001 at the Butajira weather station was 1,217 mm (data by courtesy of the National Meteorological Institute). The average monthly rainfall in the same years exceeded 100 mm March-September, with peaks in March and July-August. For the months November-January, average rainfall was below 50 mm, frequently 0 mm in single years.

The terms lowland and highland are commonly used, but are as much indicators of differences in cultural and agricultural practices as of actual altitude. Since the lines between the two follow administrative boundaries when villages, kebeles, are classified as either low- or highland there is considerable overlap of “low”- and “high”-land around 2,000 m above sea level. Among features that differ because of different topography, are the natural water sources, with a few small meandering wet-season rivers on the lowland plateau and more of natural springs and streams in the hilly parts of the highland areas.

Drinking water in the rural areas is taken from rivers, dug wells or from one of the growing number of drilled, protected wells. It is still common during the rainy season to fetch water from standing pools, since the distance to better quality supplies may be great.
As in all Ethiopia, the economy is based on agriculture and the majority of the population are subsistence farmers. Climatological and cultural differences between low- and highlands lead to differences in agricultural production within the Butajira district. Maize and pepper are important cash crops in the lowland while ensete, an indigenous plant typical of the Gurage zone, is more common in the highlands. The indigenous cereal teff is grown mainly as a cash crop, not only in lowlands. The lowland areas have more of monoculture and some larger farms. Cash crop production crop production is more common in the lowlands. In part of the highland areas khat is an important cash crop.

Since the overthrow of the last emperor in the nineteen-seventies, land is primarily state owned in Ethiopia and the right to use farm land is delegated to kebele control, where there is considerable overlap between modern, “political” control and traditional village leadership. In theory, land is distributed according to needs of the family or household and may be redistributed after changes in family size. At the same time, it appears that the right to farm land may be sold and bought. Within the DSS sample, 75% of the rural, farming population lives on farms with less than four timad, i.e. less than two hectares (Berhane Y, Wall S, Kebede D, et al 1999).

At the same time there are traces of economic growth and technical development in the rural areas. In some places, households that can afford it are provided with electricity, from privately owned generators using surplus energy from the diesel engines that operate local, privately owned flour mills.

Butajira town is situated in a classical market town location, at a ford where a major road crosses a river. The road is one of the main roads to southern Ethiopia which branches off south from a major road west out of Addis Ababa. Beyond Butajira it is the main transport route from Addis Ababa to the southern cities of Sodo and Arba Minch, 250 kilometres south of Butajira. Besides the district administration, the police station and the district court, the secondary school and district health centre, the market was the most important feature of economic and societal activity.

Butajira has grown to be one of the major market towns along this road. The market place was once where townspeople and farmers from the district met to exchange goods. It is now no longer a place for local piecemeal trade only but where traders buy in bulk from local producers. The growth of a local middle class has opened opportunities for modern shops and recently for budding supermarkets.
setting and methods

The all-weather road from Addis Ababa that was constructed during the Italian occupation, 1935-41, has been gradually improved and upgraded to modern standard in the last decade. The shortened transport time from Addis Ababa, previously at least five hours by four wheel drive vehicles, now one and a half hours by ordinary car, has led to great increases in travel and trade. Butajira has become a node of transport which shows in the increasing number of good hotels, and the influx of NGO offices. At the time when the BRHP collaboration in the district started, the standard of the local hotels was such that project staff from Addis Ababa spent the nights during field work in Ziway, fifty kilometres by gravel road to the east of Butajira town.

During the last decade the town has undergone great changes. Not only have hotels improved and multiplied and shops developed from hole-in-wall enterprises to small supermarkets but telecommunications have improved to a situation where fixed telephony is at least as reliable as in Addis Ababa and the town itself has good mobile telephone connection. There are several Internet cafés.

As late as the late nineteen-nineties, most of the town was not electrified and electricity supply was uncertain. The river on the northern side of the town by the ford, was replaced as source of drinking water for the town as late as 1980, when a municipal supply of piped water began to be introduced and gradually expanded. You still see townswomen and children carrying water or transporting it on donkeyback from the river.

A general impression is that much of the development that can be seen, in the town as well as in the rural areas, arises from private sector initiatives. The most common occupation in the town is small scale business, with growing public sector and NGO employment.
There is a tradition of trading in the Gurage zone, where many have moved to Addis Ababa to start out on a small scale. Hole-in-the-wall shops along the streets in Addis Ababa are commonly called “gurage shops.” The big investors in Butajira are successful business people from Addis, bringing money back to their home town to build multi-storey hotels and shopping centres. There is now also at least one private college, offering training in both management and nursing. Investment seems to be mainly in property and services, little is invested in industrial production.

Less has happened in the public sector, besides the improvements in roads, telecommunications and the town water supply. Since the previous government, the kebele provides low quality but very cheap housing for rent to the poorest. These are houses without any modern facilities. The town has one technical school and one upper secondary school that serves the entire district. In the rural areas there are 28 primary and lower secondary schools. Most rural children still do not complete lower secondary school and many not even complete primary school. Few complete any level of school at the expected age since children, especially in the rural areas, are compelled to work.

In the 1994 National census, school enrolment figures for the Meskan and Mareko wereda show that less than 8% of all children age 7-12 were enrolled in primary school, 9% of the boys and 6% of the girls. Among the urban children, 33% of those aged 7-12 years and in the rural areas only 4% were enrolled in primary school (5.5% of the boys and 2.7% of the girls). The preliminary report from the 2007 census does not give statistics on education. In the 2005 Ethiopian Demographic and Health Survey, EDHS, the sample was too small to allow breakdown to wereda level. The figures for the entire SNNPR show that school enrolment has improved over the approximate decade. Still only 35% of all children aged 7-12 were at all enrolled in primary school in the 2005 DHS sample, 37% of the boys and 32% of the girls.

**Health services**

The health services provided at the time when the Butajira DSS began its population follow-up was one Health Centre in the town which was established in 1976. The nearest referral hospitals were the regional hospital in Hosaina, approximately 100 kilometres south of Butajira and the hospitals in Addis Ababa, 130 kilometres away by road (Berhane Y, Wall S, Kebede D, et al 1999). During the 1990s two government Health Stations and 11 rural Health Posts, were introduced in the district and a number of private clinics were established. Under the influence of international policies, the public
health care system was expected to charge the patients for services. The system was one where original seed money for drugs and health worker salaries should be replaced in a revolving funds system. A system of exemption for the poorest was intended to reduce the more extreme inequities of such a system. The exemption system is still in action, based on evaluation of households' economic capacity, assets and income, by the kebele leadership. It seems that a combination of low rate of replacement of the funds at least partly due to this exemption system, together with recurring shortages of drugs led to a situation where Health Posts were mostly non-functional. A qualitative pilot study in 2000, preparing for a study of intimate partner violence, recorded that women have little control over the use of what little money may be available to the average household: According to the women, health care came low on the husbands' list of items to spend such money on (Berhane Y, Gossaye Y, Emmelin M, et al 2001).

The regional Health authority has a malaria control office in Butajira, with a simple laboratory facility. Malaria infection has been regularly surveyed and spraying and bed net programs have occurred occasionally. A recent health care reform programme, the Health Service Extension Programme has been implemented in the Butajira area since 2003/4. Focus is on prevention and health education in the rural areas and at village level. The programme builds on employing and training women as Health Extension Workers (Fantahun 2008, p 18).

In the late nineties, a local initiative was taken to build a hospital in Butajira town. Local committees raised funds through collections locally and through international NGOs and other donors. Once construction was completed and funds had been raised for basic furniture and equipment, the hospital was taken over by the government. Since 2001, activity has gradually grown from the most basic services, though staffing is still a problem.
Within the BRHP project family an intervention study of management of the most common childhood illnesses involved all nine rural villages in the DSS sample during 18 months, 1994-96. Health Posts, one in each kebele, were established. These Health Posts were staffed by part time “Community Health Agents” recruited among the local farmers and trained to diagnose and treat the most common childhood illnesses. The Health Posts were kept supplied with drugs (cotrimoxazole, fansidar, chloroquine, oral rehydration salts, paracetamol and ointment). The service and treatment were free of charge for all children under five years of age. The study used a step-wedge design where three kebeles were included in the intervention each three months, with a total follow-up of eighteen months (unpublished). After the intervention the health posts lapsed due to lack of sustainable funding.

Within the framework of a study of indoor air pollution (paper III) a similar intervention was introduced in the nine rural kebeles for approximately two years April 2000 – May 2002. The study was focusing on measurements of NO$_2$ as pollutant indicator in relation to Acute Lower Respiratory Infections. Besides providing service for the population, the intervention was used to increase case ascertainment. Under the intervention the Health Posts from the previous intervention were reopened and stocked with drugs and the community health agents retrained. All treatment was free of charge for children under five and to improve case finding, the intervention was widely advertised by word of mouth by the project data collectors at the beginning and at each regular visit to the children’s homes for NO$_2$ sample taking and interviews (every three months). The cost per year of salaries and drug supplies for running the Health Posts was 0.7 USD per child (2001).

**The population**

The Southern Nations, Nationalities and Peoples Regional State is the third largest of the states within the Ethiopian federation in terms of population. In the 1994 census the SNNP region had a population of 10.4 million inhabitants$^4$. 47% were under the age of fifteen and 24% over sixty-five$^3$. The population of the Meskan and Mareko Wereda, the Butajira district, was 227,135 with 13% living in the urban area. 50.2% of the entire wereda population were females, 51.4% in the urban area and 50.0% in the rural areas.

According to the 2007 census the SNNP population by then was approximately 15 million inhabitants (Central Statistics Agency 2008). The annual population growth rate 1994-2007 was 2.9%, which is slightly over the national average of 2.6%. Approximately
90% of the region’s population live in rural areas. Of the entire population in the zone, 50.3% are female, 50.5% in the rural areas and 48.4% in the urban. 45% of the population is under fifteen years of age and 24% over sixty-five. The division of the former Meskan and Mareko district and redistribution of the kebeles make it impossible to establish the 2007 census population of the district from which the DSS sample was originally drawn. Assuming the same growth rate as in the region as a whole, the “Butajira district” population of 2007 would be just under 330,000. The rural-urban distribution would not be possible to estimate, since the urban and rural growth rates are not known.

The role of women in Ethiopia is as in most other parts of the world a matter of carrying the double burden of participating in the breadwinning activities, farming or trading, and doing whatever of the household work that is not taken over by daughters. Where there is scarcity of both water and firewood, several hours per day may be spent carrying water from far and collecting firewood. Some of this work spills over on the children increasingly with increasing age.

The girls start by tending smaller siblings and gradually takes over household chores according to their capacity. The boys, when they are not minding goats and cattle or helping with farm work, may help carrying water.

Most rural households live in extended family constellation and also in the town, families with property may stay in households of two- or three generations. In the rural areas the newlywed woman moves to the husband’s compound

**The sample population**
The population that is included in the demographic surveillance is the population of nine rural kebeles and one urban kebele from Butajira town drawn from the originally 82 rural and four urban kebeles in 1986. The sample of ten kebeles was taken as a cluster sample based
on probability to size (pps sampling). Probabilities were based on size of the population of the kebeles according to the latest previous national census, in 1984. The boundaries of the original kebeles have been kept as boundaries of DSS units through the various changes in wereda demarcation and redistribution of kebeles or sections of kebeles throughout the total follow-up from 1986 to present.

An initial baseline census was performed in April 1986, after which surveillance proceeded. In order to let the staff and surveillance methodology come to agreement, the baseline cohort was defined as persons included on January 1st, 1987 (Shamebo D, Sandström A, Wall S 1992). That population is now referred to as the baseline population.

Of the nine rural kebeles included, four are lowland and five highland areas. The sample was taken so as to represent as wide variety as possible in topography, agriculture and climate as well as to include both rural and urban areas.

The baseline population consisted of 28,616 persons, 13,801 male and 14,815 female. 13,972 lived in rural highland kebeles, 10,255 in the lowlands and 4,389 in the quadrant of Butajira town that was included in the sample. 4,297, 15% were under five years of age and 48% were under fifteen, reflecting the characteristic age pyramid of a
low-income setting. Of the under-fives, 1,968 lived in the highlands, 1,625 in the lowlands and 704 in the town. 3% of the population in the sample kebeles were over 65 years of age.

Over the years the sample population has grown. In 2004, eighteen years after the start of surveillance, the mid-year population in the DSS sample was 53,482. The mid-year population, births and crude birth rates for a series of years 1987-2004 are shown in table 1.

<table>
<thead>
<tr>
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<th>1987</th>
<th>1993</th>
<th>1999</th>
<th>2004</th>
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<td>mid-year pop.</td>
<td>29,406</td>
<td>35,077</td>
<td>44,075</td>
<td>53,482</td>
</tr>
<tr>
<td>births</td>
<td>1,884</td>
<td>1,671</td>
<td>1,404</td>
<td>1,547</td>
</tr>
<tr>
<td>birth rate (/1,000)</td>
<td>64.1</td>
<td>47.6</td>
<td>31.9</td>
<td>28.9</td>
</tr>
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Table 1. Mid-year population, births and crude birth rate, 1987-2004, selected years

**Surveillance**

After the initial baseline census the surveillance started, with monthly rounds of visits to all households included in the sample. All individuals in the baseline population were registered in a database to which surveillance information was added, gradually building a longitudinal database. (Berhane Y, Wall S, Kebede D et al.1999)

In the first years, the database was organised as a simple spreadsheet in a statistics software package, QUEST, that had been developed in Umeå university. Eventually the complications of storing longitudinal data in such a format led to development of a Foxpro-based relational database. The new storage system allows recording of multiple episodes of repeatable events, such as in- or outmigration, changing marital status or change of house for each individual. The key to all information related to an individual lies in her/his ID-code, while characteristics common to the members of a household are recorded as household data identified by a household code. Longitudinal datasets for epidemiological analysis have to be specially compiled from the database for the purposes of a specific study and depending on what individual- and household related data from the surveillance are needed. The database as a whole makes up an open, dynamic, cohort of all persons that ever lived in the sample kebeles as regular inhabitants.
As “enumerators”, demographic data collectors, were employed persons with at least ten years of formal schooling. The enumerators were trained in how to conduct interviews, the manual for the field work and the management of data in the field. All interview forms are printed in Amharic. The interviews are done in Amharic or in a local language.

A supervisor in the project office in Butajira town oversaw the daily work and checked on the data quality. Data quality control was done by reviewing the completed forms submitted by enumerators and by re-interviewing randomly in the field. This function has been gradually developed in order to improve data quality. Checks in data entry and routines for referral back to the field have been introduced to further increase quality assurance in the database management.
In the first years, data collection was done by enumerators that were based in Butajira town. As that often meant spending a great part of the working day on moving to and from the locations, local, village based enumerators were recruited, at least one for each kebele. Over time, the organisation has grown to include not only a larger number of enumerators in recognition of the growing population. An increasing number of special studies have used the research infrastructure that the BRHP offers. This makes demands on enumerator capacity and on the capacity to train and supervise enumerators that are short term employed for a specific study. The initial project manager and supervisor has been replaced by an organisation of several supervisors, each with responsibility for one or two of the sample kebeles, an office manager, a data entry clerk and a cleaner. Two drivers are employed for transport between Addis Ababa and Butajira. The single room, rented office space of the first years has been replaced.

The current project premises include two buildings in a project compound, one for office and storage space and one, with a sporadically functional bathroom, as accommodation and workspace for visiting staff from Addis Ababa.

Besides the running quality control, re-census activities have been used at irregular intervals to check the database against the population in the field. While surveillance only adds information into the database on new vital events such as births, deaths, marriages and in- and out migration, the census checks the information by tracing individuals from the database to the field and creating lists of all individuals reported present at the time of census. Such re-census activities have been performed in 1995, 1999 and 2004. The 2004 round of re-census was planned to be followed by a new system of “reconciliation” of database and field performed on a rolling schedule every year. Due to diminishing core funding, this has not been possible.
Original surveillance was done as monthly rounds of visits to each household. After the census in 1999, it was decided to try quarterly rounds. One reason for this was concern over “informant fatigue”, that the households would object to being visited at too short intervals for answering the same questions. At the time, several studies were going on simultaneously and the concern was that households would refuse to participate. Another reason was the wish to cut the cost of field work. After piloting, the surveillance interval was changed to three months. The work was then divided into two months of field work and one of quality control. Data entry runs continuously.

**The data**

Data collection in the regular surveillance and in the re-census or reconciliation differ in content. Surveillance concentrates on information concerning *individuals*, vital events data including births, moves in and out of the kebele, changes in marital status (marriage, separation, divorce or death of spouse) and deaths, with a special cause-of-death section. In the reconciliation round, besides checking the existence in the population of persons in the data base, information on the *household* level is collected. Household data includes economic data, such as area of farm land used by the household, income, occupations of the adults, source of drinking water and the type of house, round or square, thatched roof or metal etc. The only exception to this division between surveillance and reconciliation rounds is that if a new household moves in or a new house is constructed, the relevant household information is collected at the time. The reasons for this division are several. A main reason is that such characteristics change relatively seldom in a family, compared to the vital events which are the core of the surveillance and the motive for its existence. It is important for data quality to reduce the number of questions. A disadvantage of adding household information at longer intervals is that the information may change long after the fact has changed. It also increases the possibility that the household information will be missed altogether for households that only existed between two rounds of household data collection.

Part of the analyses in this thesis rest on the cause of death information collected for all deaths in the surveillance. The method for identifying the cause of a death is the simplest possible: the next-of-kin informant id asked for her view of what the cause of death was. The cause of death question in the interview form used at a death specifies 20 alternative causes and one open-ended alternative, where the informant is asked to specify the cause if not one of those listed.
Among the causes listed are “premature birth”, “malaria”, “pneumonia”, “diarrhoea/vomiting”, and “malnutrition”. All the alternatives are given using established local terms for the corresponding diseases. In preparing the question, the concepts were explored with local inhabitants.

Since 2003 the BRHP surveillance includes a formalised verbal autopsy (VA) method, using a structured questionnaire that is evaluated by physicians or by other methods (Fantahun M, Fottrell E, Berhane Y, et al. 2006). The data from these verbal autopsy interviews are not yet analysed and so cannot be used to evaluate the quality of the next-of-kin reported causes of death collected for the same deaths as the VA information.

**Statistical methods**
The data for this study have been compiled from the BRHP data base and includes all children under five years of age that belong to the BRHP cohort. The data are organised in “episode” records, that each may cover only part of a child’s life: Thus, a child may be represented by more than one record. “Episodes” are opened and ended by events such as birth and death but also by changes in household economy, moves within the sample kebeles or in/out. The reason for this is to allow for person-time and events to be assigned to different categories as facts change for an individual.

Data used in the analyses are dates of birth and death, dates of entering or exiting for other reasons than birth or death and cause of death data according to next of kin. As a simple classification of economic status of a household, the area of land farmed by a family is used in the rural areas and ownership of the family home in the urban area. Thus, a poor rural family uses 1.5 hectares or less and a poor urban family rents its home from the kebele. The definitions are based on the distribution in the population. Approximately 75% of the families are poor according to this classification. This reflects the fact that Ethiopia as one of the poorest countries in the world has a very homogeneous population in terms of household economy.

For data management and basic analyses, EpiInfo (Epi6,v6.04d) and Stata10 were used. All mortality figures are calculated with the density method, as deaths per 1,000 person years, using the cohort software, also developed in Umeå University. These figures may differ from the standard types of estimate published for international comparison where population, or “livebirths”, are used as the denominators. The density method allows for better internal comparisons, since the weight of length of survival is taken into the denominators. Rate ratios with Mantel-Haenszel adjustment, 95%
confidence intervals and attributable proportions and attributable cases have been calculated from the incidence density estimates using standard methods.

**Ethical considerations**
The Butajira Rural Health Programme received ethical clearance by the Medical Faculty of Addis Ababa University and from the Ethiopian Science and Technology Commission. Permission was also granted by local authorities and leadership at kebele level. Informed consent has been granted by the households.
The sub-studies – papers I-V

The five papers included in the thesis are intended to show early results from a study of time trends in under-five mortality in the Butajira District (paper I) and to discuss and illustrate some important determinants of under-five mortality (papers II, III, IV and V). The results presented in the body of the thesis are meant to add to what is shown in the papers and to evaluate the impact an important determinant of mortality, or survival: where you live.

Paper 1: Trends in under-five mortality in rural Ethiopia as measured by demographic surveillance
Anders Emmelin, Mesganaw Fantahun, Yemane Berhane, Alemayehu Worku, Peter Byass, Stig Wall (Incomplete manuscript)

This paper was never completed, and by now has been entirely superseded by the analyses in this cover story, since the follow-up period is part of the 21 years of follow-up presented in the cover story. The paper was included when I applied to the Medical Faculty Board for permission to present my thesis, and so must be included here, though I decided not to complete it.

It was the initial paper planned specifically on child mortality after 15 years of follow-up in the Butajira DSS. Previously two papers on child morbidity and mortality were among the first papers from the surveillance, based on only one and two years of follow-up respectively (Shamebo D, Muhe L, Sandström A, et al 1991; Shamebo D, Muhe L, Sandström A, et al. 1994).

One study also gave an overview of age-specific mortality during the first ten years of follow-up, 1987 through 1996 (Berhane Y, Wall S, Kebede D et al. 1999).

Most importantly, the study shows the lack of downward trend over fifteen years of follow-up, up to 2001 but a pattern dominated by short term mortality peaks rather than trend and the great inequality between rural and urban children in survival chances and.

Paper II: Indoor air pollution – a poverty related cause of mortality among the children of the world.

Paper II is a review of the empirical support for the connection between indoor air pollution and acute respiratory infections, ARI, in children in developing countries. Exposure to smoke from biomass
fuels burned in unvented fireplaces has long been suspected to increase the incidence of and mortality from ARI among children. Since ARI is one of the three most common causes of death in under-fives in developing countries, the issue causes concern. The paper shows that the empirical base for conclusions concerning ARI and indoor air pollution is small. Few empirical studies of good quality have been undertaken. The conditions in the relevant environments make useful measurements of pollution exposure costly. Most studies have used proxy indicators of exposure. There is an obvious need of more research, not least since the existing results indicate a harmful effect of the exposure on ARI.

**Paper III: Use of biomass fuel is related to indicators of ARI among children under five in Ethiopia.**
Anders Emmelin, Abera Kumie, Yemane Berhane, Stig Wall, Peter Byass (manuscript)

This paper uses the data from the Ethiopian Demographic and Health Survey in 2005. It is a study of symptoms of acute respiratory infections in children under five in relation to indicators of smoke from biomass fuels. The data are collected in interviews with mothers and include information on symptoms, household economic status, and use biomass fuels. The study is based on cross-sectional symptom information concerning the last two weeks before the interview.

The results show that symptoms are more common among the exposed children, odds ratio= 1.4, statistically significant. Higher altitude, living in rural areas and household poverty also influences the risk of ARI symptoms.

**Paper IV: Magnitude of indoor NO\textsubscript{2} from biomass fuels in rural settings of Ethiopia.**

This paper is the first output from a large study of acute respiratory infections in children in Butajira, where NO\textsubscript{2} concentration in homes of under-fives is measured as an indicator of smoke. The study includes approximately 6,000 children under five in all rural kebeles of the BRHP DSS. Samples were taken, using passive diffusion samplers, in every home, every three months over a follow-up of eighteen months.
The study shows high levels of NO₂ concentration inside the children’s’ homes. The average 24-hour concentration exceeds current EU and WHO standards for annual mean concentration and is approximately half of the one-hour standards. This means that the average exposure to the children must exceed standards much of the year.

http://journals.sfu.ca/coaction/index.php.gha/article/view/1829

This paper examines a two-year period of extreme rainfall patterns in Butajira 1998-99. In other parts of Ethiopia, drought led to famine during this period. Butajira is not in the parts of the country that are regarded as food insecure (FEWS 2009), but the extremely high mortality observed by the surveillance system showed that the rural areas of the district were severely affected, first by malaria following heavy and unseasonal rains, then by malnutrition and diarrhoea. We also show that the poorest households were most affected with a significantly higher under-five mortality in 1998-99 (Rate Ratio 1.3-1.5).
Results

The under-five BRHP cohort 1987-2007

The data used for the analyses are extracted from the demographic surveillance population database of the Butajira Rural Health Programme for a twenty-one year follow-up period of 01/01/1987 – 12/31/2007. All children under five are included in an open cohort, i.e. all live-born children to parents included in the study sample at the time of birth and all children that moved into any of the surveillance areas before their fifth birthday. All children were followed from January 1st, 1987, birth or in migration, whichever came last, until their fifth birthday, death, out migration or end of follow-up, whichever came first.

The entire cohort consists of 43,966 children, 32,642 of whom were born within the DSS during follow-up while 2,078 entered as infants, either born during 1986 or in migrated in infancy later. Of the remaining 9,246 children, 5,161 were included from January 1st, 1987 born in the years 1982 through 1985 and 4,085 in migrated as one to five years old, later in the follow-up period. The age distribution at entry is shown in table 2.

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>34,720</td>
<td>2,123</td>
<td>2,336</td>
<td>2,392</td>
<td>2,395</td>
<td>43,966</td>
</tr>
<tr>
<td>%</td>
<td>79.0</td>
<td>4.8</td>
<td>5.3</td>
<td>5.4</td>
<td>5.4</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 2. Age distribution at entry into follow-up

Of the total population followed, 21,678 (49.3%) are girls and 22,288 (50.7%) boys. 18,567 (42%) of them are from the highland villages, 16,973 (39%) from the rural lowlands and 8,426 (19%) from the urban sample in Butajira town. 64% belong to Muslim families, 17% to Orthodox Christian families, and 2% belong to families of other Christian denominations, while for 17% the religion of the family is unknown. The cohort is summarised in table 3.
Table 3. The cohort according to area of residence, gender, economic status, deaths and person-time 1987-2007
* economic data missing for approx. 5% of the cohort, excluded

<table>
<thead>
<tr>
<th></th>
<th>Highland</th>
<th>Lowland</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>total (n)</td>
<td>18,567</td>
<td>16,973</td>
<td>8,462</td>
</tr>
<tr>
<td>girls (n)</td>
<td>9,145</td>
<td>8,349</td>
<td>4,184</td>
</tr>
<tr>
<td>boys (n)</td>
<td>9,422</td>
<td>8,624</td>
<td>4,242</td>
</tr>
<tr>
<td>poor* (n)</td>
<td>14,048</td>
<td>11,759</td>
<td>3,424</td>
</tr>
<tr>
<td>rich* (n)</td>
<td>3,769</td>
<td>4,397</td>
<td>4,380</td>
</tr>
<tr>
<td>deaths (n)</td>
<td>2,013</td>
<td>2,486</td>
<td>438</td>
</tr>
<tr>
<td>person years</td>
<td>62,261</td>
<td>53,764</td>
<td>25,958</td>
</tr>
</tbody>
</table>

49% of the cohort are girls and 51% boys, the gender distribution is constant over the areas. In the rural areas approximately 70% of the children live in families that are classified as poor (76% in the highlands and 69% in the lowlands) while in the town, 41% live in poor families. Data on land use and home ownership is missing for 5% of the cohort. The proportion missing is slightly higher in the urban area, 7.4%. Individuals without information are be excluded from analyses where such information is used. In all other analyses the entire cohort is included.

Of the total of 43,966 children 4,937 (11%) died. While the urban children are 19% of the cohort, they only account for 9% of the deaths. The total amount of person time experienced by the children in the cohort before their fifth birthday is 141,983 years.

Mortality by cause

All cause mortality
The total amount of person time experienced by the children in the cohort before their fifth birthday is 141,983 years. Of the total of 43,966 children 4,937 (11%) died. While the urban children are 19% of the cohort, they only account for 9% of the deaths. 2,013 highland and 2,486 lowland children died before five years of age in the
RESULTS

twenty-one years of follow up compared to 438 in the town. Rates per 1,000 person years and Mantel-Haenszel-adjusted rate ratios and confidence intervals are shown in table 4.

<table>
<thead>
<tr>
<th></th>
<th>Highland</th>
<th>Lowland</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>rate (/1,000 p-yrs)</td>
<td>32.3</td>
<td>46.2</td>
<td>16.9</td>
</tr>
<tr>
<td>Rate ratio (MH)</td>
<td>1.87</td>
<td>2.64</td>
<td>1.0</td>
</tr>
<tr>
<td>95% C.I. (MH)</td>
<td>1.69-2.08</td>
<td>2.39-2.92</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 4. All-cause, under-five mortality, 1987-2007, and urban-rural rate ratios (urban as reference)

Girls have a lower mortality than boys, 33.6 deaths/1,000 person years compared to 35.9. This gender pattern of mortality is the same in both rural and urban areas, with slightly lower mortality for girls.

The mortality pattern over the twenty-one years of follow-up is shown in figure 5.

Figure 5. Under-five mortality, 1987-2007, all causes of death
Most striking are that the urban under-five mortality remains lower than the rural mortalities throughout the entire period. There is no clear trend in mortality reduction. The most dominant impression is that of peaks, mainly in the rural areas. In the last years there is a downward turn in both rural and urban areas. The reduction is greater in the rural areas, but begin at a considerably higher level.

Crude rate ratios are consistently slightly higher than the adjusted, due to differences in age-specific infant and 1-4 mortality. The highland infant mortality rate is 84.5/1,000 person-years, the lowland rate is 99.9/1,000 and the urban 46.2/1,000 which gives infant rate ratios of 1.8 for highland vs urban rates and 2.2 for lowland versus urban rates. For the 1-4 age group the rate ratios are 1.9 and 3.3, respectively for highland and lowland versus urban mortality. In the following, Mantel-Haenszel adjusted ratios will be used for comparing the areas.

Figure 6 and figure 7 show the infant and 1-4 years time patterns.
The infant mortality pattern shows more peaks at shorter intervals, not so dominated by specific peaks. The urban mortality is more variable, with shorter periods of low levels.

Overall, the urban 1-4 group has a more constant mortality pattern, lower and with less variation. The biggest peak, in 1998-9, where the rural children more than double their mortality, hardly shows in the urban children.

Dividing the cohort according to household economy, as indicated by farm land access or house ownership, shows higher mortality for the children in the poor families. The children in the better-off homes have a mortality 1987-2007 of 29.0 deaths/1,000 person years, while the value for the poorer is 36.4 (RR_{MH}=1.22 (1.14-1.30). The group where information on economy is missing has the highest mortality, 52.8 deaths/1,000 person years.

Using the relative risks with urban mortality as the reference, we can estimate the impact of the differences between living conditions in the rural areas and the urban area. The attributable fraction for highland children is 0.47, with 95% confidence interval 0.39-0.52. For the lowland children, the attributable fraction is 0.62 (0.58-0.66)
and for all rural vs urban 0.55 (0.50-0.59). The total number of attributable cases is 2,481 rural deaths (95% C. I.: 2,271-2,670), 937 in the highlands and 1,544 among the lowland children. Attributable fractions and cases for the most common causes of deaths are summarised in table 9.

**Malaria**

501 children died from what next of kin reported as malaria. The majority of these deaths were in the lowland areas, 305, while 173 died in the highland and only 23 in the urban area. The overall malaria mortality rate was 3.5 per 1,000 person years. Of the 501 malaria deaths, 170 are reported among infants and 331 children 1-4. Rates and rate ratios are shown in table 5.

<table>
<thead>
<tr>
<th></th>
<th>Highland</th>
<th>Lowland</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate (/1,000 p-yrs)</td>
<td>2.8</td>
<td>5.7</td>
<td>0.9</td>
</tr>
<tr>
<td>Rate ratio (MH)</td>
<td>3.10</td>
<td>6.31</td>
<td>1.0</td>
</tr>
<tr>
<td>95% C.I. (MH)</td>
<td>2.01-4.80</td>
<td>4.13-9.64</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 5. Under-five mortality, malaria as reported cause, 1987-2007, and urban-rural rate ratios (urban as reference)

Boys had a slightly larger malaria mortality than girls, but the difference is not statistically significant (relative risk=1.1, 95% C.I. 0.93-1.32). There is no difference between the poorer and the more well-to-do. The time trends in the highland, lowland and urban areas over the twenty-one years of follow-up is shown in figure 8. Like for all-cause mortality, the pattern is dominated by peaks, but the two rural parts do not coincide as clearly. Mostly, the peaks are higher in the lowland and very few in the urban area. There is a small peak in 2003, when malaria mortality exceeds that in the highlands and comes close to the lowland rate. This peak has about one quarter of the reported urban malaria deaths, but still only 6 out of 23.
The proportion of the rural deaths that can be attributed to differences in conditions of life between urban and rural areas is 78%, 95% C.I. 67-86%. The total number of attributable deaths is 478. These results are summarised in table 9.

**Acute respiratory infections**
In the entire under-five cohort, a total of 660 children died from acute respiratory infection during the follow-up, giving a mortality rate of 4.6 per thousand person years. Of these deaths, 314 occurred in the highlands, 276 in the lowlands and 70 in the Butajira town sample area. Boys’ ARI mortality was slightly higher than the girls’ but the difference was not statistically significant (RR= 1.1, C.I. 0.96-1.30).

The poorer group has a higher mortality than the more well-to-do, 462 vs 153 deaths, mortality rates 4.8 vs 3.6 per 1,000 person years, adjusted rate ratio 1.3, 95% C.I. 1.07-1.53. The group that does not have data for classifying household economy has the highest ARI mortality, 9.7 per 1,000 person years, based on only 45 deaths, rate ratio with the richer as reference category is 2.7 (1.91-3.71).
Table 6. Under-five mortality, acute respiratory infections as reported cause, 1987-2007, and urban-rural rate ratios (urban as reference)

The mortality variation in the three areas over twenty-one years is shown in figure 9. Compared to the time variation in malaria mortality, ARI differs as cause of death in that it shows a pattern more like a constant level, with some smaller peaks, that could possible reflect epidemics of infections such as measles. Except in peaks, there is less difference between rural and urban areas. There is also an indication of a downward trend in the last five to six years.

Figure 9. Mortality from acute respiratory infections, 1987-2007
The attributable fraction of rural deaths from ARI related to rural conditions is 0.45, 95% C.I. 0.30-0.57. The fractions for highland and lowland are the same, 0.45. The attributable under-five deaths from the rural areas together are 266. See further table 9.

**Diarrhoea**

According to next-of-kin diagnosis, 729 children in the BRHP cohort died from diarrhoeal diseases before their fifth birthday. Of them, 356 lived in the highland areas, 307 in the lowlands and 66 in the town. The overall rate was 5.1 per 1,000 person years. Rates and adjusted rate ratios are shown in table 7. As with ARI, diarrhoeal disease mortality is more associated with rural characteristics in general and does not differ between high- and lowland living.

<table>
<thead>
<tr>
<th>Rate (/1,000 p-yrs)</th>
<th>Highland</th>
<th>Lowland</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5.7</td>
<td>5.7</td>
<td>2.5</td>
</tr>
<tr>
<td>Rate ratio (MH)</td>
<td>2.21</td>
<td>2.19</td>
<td>1.0</td>
</tr>
<tr>
<td>95% C.I. (MH)</td>
<td>1.70-2.87</td>
<td>1.68-2.86</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 7. Mortality from diarrhoea, 1987-2007, and urban-rural rate ratios (urban as reference)

Boys have a significantly lower diarrhoea mortality than girls. The mortality rates in all areas, are 4.6 for boys and 5.7 for girls, adjusted rate ratio 0.8 (0.69-0.93) with the girls as the reference group. The highland boy/girl mortality ratio is 0.78 (0.64-0.96), the lowland rate ratio is 0.83 (0.66-1.03) and the urban 0.81 (0.50-1.32).

The poorer group has a higher diarrhoeal disease mortality than the more well-to-do. This social inequity is the same in the two rural groups of kebeles, adjusted rates 1.31 (0.99-1.75) in highlands, 1.36 (1.03-1.79) in lowlands but 0.77 (0.46-1.28) in the town. The numbers of deaths among poor are 284, 233 and 23 for highland, lowland and urban populations, respectively.
Figure 10. Mortality from diarrhoeal disease, 1987-2007

Figure 10 shows how diarrhoeal mortality varies over the follow-up period. The pattern is dominated by a few peaks over a relatively lower average. The three areas show coinciding peaks in 1990-91, but the peak in 1999 is mostly rural.

Of the 663 diarrhoeal deaths, 362 (275-429-232) can be attributed to living in rural areas, an attributable fraction of 55% (42-65%). The lowland and highland fractions are equal, with attributable cases 167 and 195, respectively. The attributable fractions and cases are summarised in table 9.

Birth and the first month

Of the entire number of deaths in the BRHP, 4,937, more than half, 2,571 occurred during infancy. 42% of these infant deaths, 1,081, occurred during the first month after birth. 456 deaths in the first month of life occurred in the highland kebeles, 515 in the lowland and 110 in the town. The rate is highest in the lowlands, 33.3 deaths per 1,000 person months, compared to 41.3 in the highlands and 21.3 per 1,000 person months in the urban area. Rates and rate ratios (no adjusted) are presented in table 8.
Table 8. Mortality during the first month after birth, 1987-2007, and urban-rural rate ratios (urban as reference). N.B. the time unit is person month of follow-up.

The newborn boys in the cohort have a higher mortality in the first month after birth than the girls, 40.7 deaths per 1,000 compared to the girls’ 28.1. The boy-girl rate ratio is 1.15, 95% C.I. 1.06-1.24. There is very little difference between the poorest and the less poor, rates 34.5 and 33.6 deaths per 1,000 person months, respectively. The relatively small numbers among the urban children will not allow further breakdown into subgroups.
RESULTS

The total number of deaths in the first month that can be attributed to the conditions in the rural areas is 413, in the highland areas and 248 in the lowland kebeles. Attributable fractions are and the numbers of attributable deaths are summarised in table 9.

The urban cohort
The urban children are used here as the reference, against which to estimate rural excess mortality and the impact of the difference in conditions between the rural areas and the town. As is shown in figure 5, the urban children themselves have not experienced a major improvement in mortality rates over the twenty-one years of follow-up.

Taken in seven-year periods, the urban under-five mortality has only changed marginally. From 18.1 per 1,000 person years in the period 1987-93, there is a slight decrease to 17.4/1,000 person years 1994-2000 and further to 15.4/1,000 person years in 2001-07. The urban poor have experienced a slightly larger downward turn from 23.4/1,000 in 1987-93 to 15.3/1,000 person years in the period 2001-07 (RRM=0.72 C.I.: 0.51-1.01).
<table>
<thead>
<tr>
<th>cause</th>
<th>area</th>
<th>attributable fraction</th>
<th>attributable deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>all causes</td>
<td>highland</td>
<td>0.47 (0.39-0.52)</td>
<td>937 (786-1,045)</td>
</tr>
<tr>
<td></td>
<td>lowland</td>
<td>0.62 (0.58-0.66)</td>
<td>1,544 (1,445-1,635)</td>
</tr>
<tr>
<td></td>
<td>all rural</td>
<td>0.55 (0.50-0.59)</td>
<td>2,482 (2,271-2,670)</td>
</tr>
<tr>
<td>malaria</td>
<td>highland</td>
<td>0.68 (0.50-0.79)</td>
<td>117 (87-137)</td>
</tr>
<tr>
<td></td>
<td>lowland</td>
<td>0.84 (0.76-0.90)</td>
<td>257 (231-273)</td>
</tr>
<tr>
<td></td>
<td>all rural</td>
<td>0.78 (0.67-0.86)</td>
<td>374 (320-410)</td>
</tr>
<tr>
<td>ARI</td>
<td>highland</td>
<td>0.45 (0.29-0.58)</td>
<td>141 (91-181)</td>
</tr>
<tr>
<td></td>
<td>lowland</td>
<td>0.45 (0.28-0.57)</td>
<td>124 (77-157)</td>
</tr>
<tr>
<td></td>
<td>all rural</td>
<td>0.45 (0.30-0.57)</td>
<td>266 (175-337)</td>
</tr>
<tr>
<td>diarrhoea</td>
<td>highland</td>
<td>0.55 (0.41-0.65)</td>
<td>195 (147-232)</td>
</tr>
<tr>
<td></td>
<td>lowland</td>
<td>0.54 (0.40-0.65)</td>
<td>167 (124-200)</td>
</tr>
<tr>
<td></td>
<td>all rural</td>
<td>0.55 (0.42-0.65)</td>
<td>362 (275-429)</td>
</tr>
<tr>
<td>first month</td>
<td>highland</td>
<td>0.36 (0.21-0.44)</td>
<td>164 (97-198)</td>
</tr>
<tr>
<td></td>
<td>lowland</td>
<td>0.48 (0.36-0.58)</td>
<td>248 (187-298)</td>
</tr>
<tr>
<td></td>
<td>all rural</td>
<td>0.43 (0.30-0.53)</td>
<td>413 (292-513)</td>
</tr>
</tbody>
</table>

Table 9. Attributable fractions and deaths, urban as reference
Discussion

It is difficult to see that Butajira has experienced a reduction of under-five mortality in the order of twenty-five percent over the period 1990-2005, as suggested in the Ethiopian DHS 2005 report (Central Statistical Agency (Ethiopia) and ORC Macro. 2006.). The patterns that all-cause mortality in Butajira show, whether it is all under-fives, infants or the 1-4 age group indicate a vulnerability to epidemics and food insecurity. Only over the last years of the twenty-one year follow-up is there any clear downward turn that is not the backside of a peak. It is too early to know if the reduction that begins in all areas in 2003-04 is to be followed by another peak or whether it is indeed a trend. This downturn in itself may be consistent with the changes that the Health Extension Services programme that was introduced and the food security programme that is reported to have started in the same period (Mekonnen W, personal communication).

It can be argued that the national survey data would represent the national population while DSS results only reflect the conditions and development in the specific locality of the surveillance site. On the other hand the survey, based on a retrospective interviews with survivors may underestimate mortality through recall bias (Byass P, Worku A, Emmelin A 2007). It is also possible that recall creates uncertainty concerning dates and so increase random error in following time trends.

A central question concerning the data is that of the cause-of-death classifications, since they rely entirely on the respondents’ own perceptions of malaria, ARI and diarrhoeas as disease entities and causes of death. It would be strange if the population did not have a good knowledge of the most common diseases that kill so many of their children, but the precision in giving a cause for a specific death may be low. It is to be expected that even common diseases such as malaria and pneumonia/ARI are to some extent confused with each other, since the fever may be the most obvious manifestation of both. However, if the main concern is to estimate the population level occurrence of a disease and follow its trend it may be reasonable to accept a lower specificity than in a situation where diagnosis decides treatment (Byass P 2007).

At the same time the results demonstrate that the group level occurrence shows different patterns, with peaks at different times for ARI and malaria, rather than a general blurring that should have been the result of mixed perceptions of the two. The experience from the 1998-99 episodes also shows that the patterns follow the expected.
Malaria peaked after the drawn out, heavy rains in 1998. Figure 2 in paper V shows this more in detail, with the higher resolution of the time scale, in quarters. The pattern is consistent with the reported cause of death, in that malaria is semi-endemic in the lowland and epidemic in the highlands (Berhane Y, Wall S, Kebede D et al. 1999). The lowland peak is higher, but there is also an increase in highland malaria mortality in 1998-99. ARI and diarrhoeal disease mortality rates, on the other hand, are very nearly the same for highland and lowland under-fives.

While formalised verbal autopsy methods have been evaluated against clinical or physician based cause of death data, the simple next-of-kin method has not been systematically validated. The only exception is for the sisterhood method for determining maternal causes of mortality which is a similar method, though for a different age group and specific circumstances of death which shows a reasonable agreement (Shahidullah M. 1995). The quality of the results in this thesis will hopefully be examined when the BRHP verbal autopsy data from the second half of 2003 and onwards become available for analysis.

The ratios between urban and rural rates are not as high for ARI, diarrhoea or neonatal deaths as for malaria, which could reflect the difference in patterns of exposure to risk factors, not only in access to health education, prevention and health care. The mosquitoes are more or less confined to altitudes below approximately 2,000 metres, which means that the vector for malaria infection is available in all of the lowland areas but only in parts of the highlands. They should be less abundant in the town, which is at borderline altitude, because of fewer breeding places in the form of open bodies of standing water. In the case of the highland children, it is not unlikely that they as rural children move more between higher and lower ground than the urban children move out of town.

Comparing the mortality from ARI to those associated with malaria and diarrhoea, the ratio between urban and rural rates is lower for ARI. This might be because the risk factors, among them crowding and indoor air pollution, are not much less common in the town population than in the highland and lowland populations. The same types of fuel are common in the town, though those that can afford to may also use kerosene or butane. Very few households do not regularly use an open fire, either on an open hearth on the floor or a modern, so called “improved” charcoal stove. As is shown in Paper IV, smoke concentrations are universally high indoors, though varied. Similarly to ARI infant mortality rates differ less between the urban and rural groups. ARI and first month mortality also have the lowest
attributable fractions, in spite of being high in total deaths, in the case of neonatal mortality by far the highest. This may mean that infant and ARI mortalities are less influenced by the factors that create the urban advantage.

The gender difference in mortality from diarrhoea is consistent over the areas, though only statistically significant in the highlands. It might reflect gender differences in nutritional status, resulting from traditional customs that men and boys eat first.

The peak pattern of diarrhoeal mortality could show a dependence on external factors, which could be epidemics or nutrition and food insecurity. The 1999 peak occurs during a known crop failure period due to unseasonal rains two consecutive years (Paper V).

The main idea behind this thesis, to estimate the number of deaths that are due to the differences mainly between rural and urban areas may seem naïve. To anyone with experience from developing countries, the differences between rural and urban conditions is obvious: there are the difference in economic capacity of (at least part of) the population, the localisation of services, the access to “modern” facilities and goods. It is “normal” that public services such as health facilities are concentrated to urban areas, even though they be small rural towns, like Butajira. It is equally easy to understand that modern type sanitation and piped water supply is developed first where the population density is greatest, because the density itself creates sanitary problems. What is less easy to understand and accept is that the scarce resources are not used to create equitable conditions, whatever the differences in distance to town.

Taking the all cause mortality as the most reliable estimate, entirely independent of cause-of-death reporting, nearly 2,500 deaths could have been avoided if equitable conditions for survival, not life, had been available to all geographical areas of what was once the Butajira district.

The approximate mid-period (1997), mid-year total population of the Butajira sample cohort is less than 39,000. In twenty-one years of follow-up the differences between rural and urban areas, within a radius of less than 25 kilometres, has meant nearly 120 “extra” under-five deaths, per year. “Extra” here means surplus to what would have been expected in the rural areas, had the basic conditions for avoiding or surviving disease been similar in urban and rural areas in a densely populated region. The large number is attributable to inequities between rural and urban populations, even though nearly all are poor even by the standards of many low income countries.
DISCUSSION

Paper V shows how vital it is to follow mortality trends, not only in the short term to provide early warning to the authorities, but also in the longer term in order to identify emerging disease patterns associated with climate change. Irregularity in weather patterns and changing regularities are typical symptoms of climate change, rather than the evenly rising averages of popular perception.
Conclusion

In order to produce change, research must lead to dissemination, often sorrowfully neglected. The BRHP has generated a vast amount of useful data and a large amount of focussed research that has been reported scientifically and in that way contributed to the pool of knowledge about disease and public health in low income countries. A number of specific problems have been addressed and useful publications have reached the scientific and public health communities.

The most immediate, with hindsight the most obvious, knowledge from the 21 years of BRHP has not been systematically reported where it belonged: in the local community of the Butajira District. While researchers studied specific problems, that were identified within the scientific community without necessarily having local relevance until it was shown by that research. Problems such as inter-partner violence, exposure to indoor air pollution, mental distress and disorder have rightly been given priority. However, the simple facts of how mortality is distributed within the population have not been continuously told to those that might have worked for change or put pressure on such persons, even though those facts were continuously collected and only needed simple compilation and dissemination.

Making the results available to their rightful owners, the population, should be recognised as a necessary process of empowering the population to take responsibility for their own health. It is appropriate to conclude with a quotation from Last’s Dictionary of Epidemiology, taken from the definition of field epidemiology: "The task of a field epidemiologist is not complete until results of a study have been clearly communicated in a timely manner to those who need to know and an intervention made to improve the health of the people" (Last 2001).
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How this came about
As a young schoolboy, I was brought into what was then a peaceful and rather nerdy world of what later became known as environmental activism. I joined a campaign that gathered trash along the shores of southern Sweden. One thing led to another, this was in the sixties and activisms were plentiful. To question consumism and its manifestations along shores and highways was only a step from questioning other aspects of the establishment. I was drawn into solidarity movements. Together with a large number of others I was proud to be among the first to be branded as hooligans because we did not think human rights issues were irrelevant in international sports exchange.

When I realised the need to get a more ordered future, I came to Umeå as one in the first batch of students in the new Environmental Health Inspector programme. I became fascinated by the 1970s "miasma theory": that air pollution must cause disease, and not least by the apocalyptic idea of a coming epidemic of environmentally induced cancers. Eventually, I found myself in a two-sided initiation: into teaching in environmental health and into epidemiology. My teaching attempts led from basic chemistry and toxicology to air pollution and further to physical planning. Epidemiology gave me some insight in epidemiological methods and an invitation to apply my teaching experience to epidemiology. Today, I am both sad and proud to note that of those in the Epi Division who went through the ordeal of thesis writing ahead of me, approximately thirty per cent at one time or another were my students in the epidemiology course.

When everybody around me went to Africa, I vowed not to impose my limited knowledge on nations already underprivileged. My contention was that whatever I knew would only be useful in a "modern" context. An Ethiopian friend asked some pertinent questions about air pollution measurements and persuaded me that my knowledge of that might be useful to address his finding of the "no-window mortality" in Butajira. He had found that not having a window in the home increased under-five mortality significantly.

Once in Ethiopia, I found there was no way back; I fell in love with the country, the climate and the friendly people, who seemed to me so Swedish in their reserve, their tendency towards bureaucratic attitudes and their reluctance to voice uncomfortable truths to a friend. The three weeks I spent in the field, walking around the rural areas taking air pollution samples and interviewing families concerning fires, smoke, firewood and cooking were among the most enjoyable weeks of my entire life. The experience of being welcomed
into the homes of strangers, laughing together over the stupidity of this ferenj asking questions about the most obvious and well known things was overwhelming. Some years later I was happy to find myself appointed Swedish co-ordinator of the BRHP.

This thesis is the third I have begun. To be quite honest, this one grew from the realisation that I had publications sufficient for a PhD on a topic that concerned me, though it was not my main focus of research. It seemed expedient to finish without completing the very long and complex series of analyses needed for the Indoor Air Pollution study that brought me to Ethiopia.

During the year I have spent trying to write this last thesis, changes have come about that have made me realise that it is a thesis I urgently needed to write for my own sake. The changes in funding for the BRHP has led to uncertainty concerning the future of our collaboration with the Ethiopian colleagues. I am convinced that these changes will lead to new life for the collaboration, but I also feel that it is time to write a part of the story of that collaboration, by writing the history of an open cohort drawn from the demographic surveillance in the Butajira District. I came there to study the air pollution exposure of the children of that population and so there was a focus on the children.

I have not attempted to write a very theoretical thesis, since I feel that the plain story of child mortality speaks for itself. I also think I am a basically empirical person. Too empirical, probably. If I were to do this again, which I promise to spare my family and colleagues, I would start by spending a year on only reading.
Acknowledgements

There is, at this terminal stage of a long process, a tendency to feel grateful to everyone at hand, perhaps most because of the happiness over seeing the light at the end of the tunnel. There is also a risk of forgetting some of those who meant much while it was going on. I have tried to recall the process and apostrophise those that meant something to this work. There are also many persons that I like and whose existence has made my life nicer. My hope is that they will know the difference.

First of all, my main supervisor for two projected theses and the finally completed one: Stig Wall. By now we have worked together so long and in so many capacities, that it might seem easy to forget to what extent you have been my mentor and my ideal. I can assure you that I have not forgotten. You introduced me to epidemiology in a way that made it impossible not to be fascinated. Your focus on the subjects, not objects, of population research is one of the many things I hope I have successfully copied.

My co-supervisor, Peter Byass, came into my PhD student life as late as at the beginning of the last thesis. With your knowledge and understanding of DSS methodology, you helped me realise that I was not alone in thinking that these esoteric technicalities of field work are worth one’s attention. My main problem in our collaboration has been the feeling you give me of being on an escalator going the wrong way. I have to run to keep up. Our visits to the Kruger park has made up for some of that.

Yemane Berhane was the person who first explained Ethiopia to me. You did it in a way that I have later realised reflects your own outstanding knowledge, understanding and feeling for the topic. You are the friend who became a co-supervisor and I know that the friendship survives the termination of the supervision.

Others that were important during my initiation into the Butajira Rural Health family were Lulu Muhe, who persuaded me that there is air pollution in Ethiopia and invited me to come and measure it. He introduced me to the original master of Butajira, ato Yemiru Teka, once the only one who really knew what was going on. Another friend I made on my first visit to Ethiopia was Derege Kebede who shared my interest in indoor air pollution and who initiated me into the mysteries of Ethiopian provincial cooking, not least into where not to eat in Butajira. Other colleagues that have become friends are Mesganaw Fantahun, Alemayehu Worku, Wubegzier Mekonnen, Fikru Tesfaye, Fikre Enquselassie, Negussie Deressa and Shabbir
Ismail who have all made my stays in Ethiopia and not least the field trips to Butajira both rewarding and enjoyable.

I am grateful for the help and the friendliness I have received from staff in the Butajira office. Among them are Wzo Shewbeza, ato Kibru, all the supervisors and enumerators whose names I could never spell but whose faces I remember. In the Addis department office there have been Beki, Yegomawork, who taught me so much in the field, drivers Freho and Fikre, Ethiopia and a lot of others I remember without names (including the two young men who drove the espresso machine in the staff canteen). One person has a special place in my heart: Abera Kumie. The indoor air pollution project would never have come to the point where it now is, without your unfailingly hard work. I am looking forward to doing the analyses and writing together with you soon.

The chance to stay at AHRI during my visits to Ethiopia has left me with many happy memories. Abraham, Howard ato Hailu and the inimitable Sven did much to make my stays pleasant as of course wzo Tsehay and her colleagues.

Many people in Umeå can claim a right to be mentioned here. Ulf, Göran, Sonny and Doris, Lars L and Curt, you have all shared the experience of BRHP with me. Ulf and Göran were pioneers there before me. Some have made my life not only more enjoyable, but easier during my travel with the BRHP. Anna-Lena has always showed great patience with my inability to understand the need for plausible, if not correct, accounts. There was a time when you spent as much time as I did on getting funds through to the black box of the indoor air pollution project account in Addis Ababa University. I hate to think of the day you retire to leave me to face an official audit.

Two persons must be mentioned, as friends, but most of all as the other two pack mules who took on my share of our common load in the last months: Karin and Curt. It was nothing you chose, but you did it all the same and you have my everlasting gratitude.

Only a few persons remain. First, the two big M’s of my life: Mesfin and Maria.

Mesfin Belete, the one and only, twenty-four hour friend, reckless driver, one-time guard of the “American ambassador’s wife”. I will never forget the times you and I have had together in the car, talking without a common language.

As for Maria, the one-time American ambassador’s wife, there is little to add to what you already know. I might have been able to go
through with it without you but there would have not been any joy in anything without you. How you put up with me, I can not tell, but I am happy as long as you do.

Our children, Eva and Axel, have listened patiently to my lament over hard work, late nights and early mornings. Axel helped me create the picture for the cover better than I had imagined it. He has also provided some of the best pictures, taken in our Butajira travels together. And Eva, well, she will soon be forgetting the previous generation in her concentration on the next.

For all those who should probably also have been mentioned, I specially want to travesty Duke Ellington: I do love you all madly! Amesege nalehu!

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