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Millennium Development Goals in Nicaragua

Analysing progress, social inequalities, and community actions

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Abstract
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The world has made important efforts to meet the Millennium Development Goals (MDG) by 2015. However, it is still insufficient and inequalities prevail in the poorest settings. We tracked selected MDG, barriers for their achievement, and community actions that help to accelerate the pace of their accomplishment in two Nicaraguan communities (León and Cuatro Santos).

In the first two studies we track the progress of MDG4 (reduce child mortality) using the under-five mortality rate. Inequalities in mortality were mainly assessed by means of maternal education, but other social stratifications were performed on rural-urban residence and sub-regional comparisons between both communities. The last two studies describe community interventions in Cuatro Santos and their association with progress toward MDG1 (poverty reduction). Participation in interventions and poverty were visualized geographically in this remote rural community between 2004 and 2009. Other selected MDG targets were also tracked.

These communities will possibly meet MDG4 even before 2015. In León, MDG progress has been accompanied by a decline in child mortality. Despite social inequalities with regard to mortality persisting in education and places of residence, these have decreased. However, it is crucial to reduce neonatal mortality if MDG4 is to be achieved. For example, in León the percentage of under-five deaths in the neonatal period has doubled from 1970 to 2005. In the remote rural area of Cuatro Santos, progress has been accelerated and no child mortality differences were observed despite the level of a mother's education.

Cuatro Santos has also progressed in the reduction of poverty and extreme poverty. The participation of the population in such community interventions as microcredit, home gardening, technical training, safe drinking water, and latrines has increased. Microcredit was an intervention that was unequally distributed in this rural area, where participation was lower in poor and extremely poor households than in non-poor households. In those households that transitioned from poor to non-poor status, microcredit, home gardening, and technical training were associated with this transition. Furthermore spatial analysis revealed that clusters of low participation in interventions overlapped with clusters of high poverty households.

Keywords: Millennium Development Goals, child survival, poverty, inequality, interventions, spatial model, Nicaragua

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To the memory of
Mi Tía Maura

List of Papers

This thesis is based on the following papers, which are referred to in the text by their Roman numerals.

I   Pérez W, Peña R, Persson LÅ, Källestål C. (2011) Tracking progress towards equitable child survival: neonatal mortality challenges to meet the MDG 4. *BMC Public Health*, 11:455[*]

II Pérez W, Eriksson L, Zelaya Blandon E, Persson LÅ, Källestål C, Peña R. (2012) Comparing progress towards the child mortality Millennium Development Goal in León and Cuatro Santos, Nicaragua, 1990–2008. *Manuscript*

III Pérez W, Zelaya Blandon E, Persson LÅ, Peña R, Källestål C. (2012) Progress towards millennium development goal 1 in northern rural Nicaragua: Findings from a health and demographic surveillance site. *International Journal for Equity in Health*, 11:43[*]

IV Pérez W, Selling K, Nazmul S, Peña R, Källestål C, Persson LÅ, Zelaya Blandon E. Community development actions to achieve the Millennium Development Goals. An analysis based on a surveillance site in Cuatro Santos, Nicaragua. *Manuscript*

[*]The article has been published in an open-access journal.

Contents

Abbreviations

AARR	Average Annual Rate Reduction
APR	Adjusted Prevalence Ratio
APRODESE	Association for Economic and Social Development El Espino
CI	Confidence Intervals
HDSS	Health and Demographic Surveillance Site
HDI	Human Development Index
HR	Hazard Ratio
IMR	Infant Mortality Rate
INDEPTH	International Network for the Demographic Evaluation of Populations and Their Health in Developing Countries
IMCI	Integrated Management of Child Illness
IPA	Innovation for Poverty Action
LMIC	Low- and Middle-Income Countries
MDG	Millennium Development Goals
NMR	Neonatal Mortality Rate
OR	Odds Ratio
PS	Propensity Score
SEP	Socioeconomic Position
UNDP	United Nation Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
U5MR	Under-five Mortality Rate
UBN	Unsatisfied Basic Needs
WHO	World Health Organization

Glossary

Confidence interval: Used for statistical inference, it is the range of values where the true parameter is expected to be within a certain level of confidence (generally stated as 95%).

Formative evaluation: Process evaluation to assess the performance of an intervention before it has been concluded.

Hazard ratio: Employed in survival analysis, it is the ratio of time to event between two groups.

Infant mortality rate: The probability of dying before the age of one year, expressed per 1000 live births.

Neonatal mortality rate: The probability of dying during the first month of life, expressed per 1000 live births.

Prevalence ratio: A ratio of the prevalence of an outcome in a certain group and the prevalence of the same outcome in other group (group might be the exposure level).

Propensity score: The probability of treatment or intervention assignment conditional on the observed baseline characteristics.

Spatial scan test: Statistical method used to detect if spatial clusters of an event have occurred by chance.

Under-five mortality rate: The probability of a child dying by age of five years, expressed per 1000 live births.

Preface

In 2002 I graduated as a mathematician from the National University of León, Nicaragua. I then was hired as a research assistant at the Center for Demographic and Health Research (CIDS) in the unit of Demography and Child Health. My work was primarily concerned with the quality control of data collection at the Health and Demographic Surveillance Site in León. In 2008 I defended a Masters thesis on "Pattern of Migration in the León Municipality".

During the course of several meetings with people from the community, I had the opportunity of disseminating information gathered by the Health and Demographic Surveillance Site (HDSS) on issues related to demography, health, and socio-economic conditions in León and Cuatro Santos. I enjoyed the discussions and witnessing the ability of people to utilize the HDSS data to solve practical problems in their communities. In 2009, I was accepted as a PhD candidate in International Maternal and Child Health at Uppsala University. My studies focused on monitoring Millennium Development Goals in local contexts in Nicaragua as part of a sandwich program between Sweden and Nicaragua, funded by Sida/Sarec.

Introduction

Human development

In October 2012, the planet earth received inhabitant number 7 billion; by 2050 a population of around 9 billion is expected (1). This rapid population growth challenges the balance between such basic resources as food and health for human development.

To define and understand human development is complex. A conceptualization like "the process of enlarging people's choices" from Amartya Sen's work on human capabilities has been considered as one approach. Choices here refer to all the alternatives people have for assuring their well-being (2,3). The United Nations Development Programme report utilized concepts similar to this definition enclose, and in creating a Human Development Index (HDI) containing three dimensions: health, knowledge, and standard of living. The index has been criticized for not including other dimensions of human development (e.g., justice, civil participation), for failing to account for social stratification (i.e., gender), and for giving equal weight to dimensions or adding together these different dimensions (4-6). Nevertheless, the HDI is one of the first attempts to visualize human development beyond an economic perspective. The index has values ranging from 0 (low human development) to 1 (high human development).

Since 1990 the United Nations has produced reports using the HDI that show the level of human development of worldwide countries (7). In 1990 that HDI went from 0.19 (Nigeria) to 0.87 (Australia); by 2011 the spectrum extended from 0.29 (Congo) to 0.94 (Norway) (8). Global assessments show that human development has improved from 0.59 in 1990 to 0.68 in 2011. However, this trend is not the same everywhere, China, for example, has the highest increase of development, going from 0.49 in 1990 to 0.69 in 2011. On the other hand, Congo has maintained its HDI at 0.29 since 1990. In countries with low HDI children die at an early age, people have less education, and they live in precarious environments without access to safe drinking water or sanitation. A way forward toward increasing human development was the Millennium Development Goal (MDG) initiative.

Millennium Development Goals

In the year 2000, 147 nations worldwide committed to reduce the level of poverty in low- and middle-income countries (LMIC) along with those social conditions related to it, such as a high burden of morbidity, mortality, unhealthy living conditions, and social injustice. The plan designed for this purpose was called Millennium Development Goals. By 2012 the total number of nations that have joined has risen to 192 (9).

The principles of human development along with sustainable development are endorsed in strategies to define, measure, monitor, and evaluate actions undertaken to meet the MDG (10). The MDG have three primary characteristics: First, they have a specified time period in which to be accomplished. Even when they were ratified in 2000, their inception point was 1990, and the deadline set as 2015. Second, progress should be monitored and continuously evaluated. This is possible as the MDG have a framework of eight goals, 18 targets, and 48 quantifiable indicators (Table 1). Third, the will of each nation to improve the lives of its people forms the cornerstone of the project.

Table 1. *Millennium Development Goals and selected targets*

MDG	Target
MDG1: Eradicate extreme hunger and poverty	Halve the proportion of people that live on less than $1.25 a day between 1990 and 2015
MDG2: Achieve universal primary education	Ensure that, by 2015, 100% of country's children will complete a full course of primary schooling
MDG3: Promote gender equality	Eliminate gender disparity in primary and secondary school by 2015
MDG4: Reduce child mortality	Reduce by two-thirds the under-five mortality rate between 1990 and 2015
MDG5: Improve maternal health	Reduce by three-quarters the maternal mortality ratio between 1990 and 2015
MDG6: Combat HIV/AIDS, malaria, and other diseases	Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases
MDG7: Ensure environmental sustainability	Halve the proportion of people without sustainable access to safe drinking water and basic sanitation
MDG8: Develop a global partnership for development	In cooperation with developing countries, develop and implement strategies for decent and productive work for youth

MDG progress in the world: poverty and child survival

The global situation

About 1.3 billion people were living on less than $1.25 a day at the end of 2008, and between 850 and 920 million were undernourished (11,12). In 2011, an estimated 61 million children were not in school (13). In 2011, 6.9 million children under age five died and 274,000 maternal deaths occurred (14,15). In this year about 34 million people were living with HIV (16); 783 million did not have access to safe drinking water, and 1.1 billion lacked adequate sanitary facilities (17).

The United Nations has been issuing annual reports on the progress of MDG since 2005. If a country is making progress toward a specific MDG, then it is considered "on track" or "target met". Otherwise its progress is "insufficient". There has not been uniform progress towards all the MDG in all countries (18,19). The World Bank estimates that about two-thirds of developing countries are on track to achieve the MDG. More than 90% are progressing in education (MDG2) and gender equality (MDG3), 88% in access to safe water (MDG7, target 3), and between 77% and 80% in reduction of poverty and hunger (MDG1, targets 1 & 3). Nonetheless, slow progress has been observed in the case of the health-related MDG (child mortality and maternal mortality (20-23).

Poverty: definition, measure, and millennium progress

Poverty reflects how people live in term of financial resources or social deprivations (e.g., health)(24). It is a theoretical and methodological challenge to attempt to define poverty (25,26).

Ways of measuring poverty serve different needs. Poverty measurements illustrate the burden of poor people, enable comparisons, assess trends, aid in implementing solutions, and evaluate policies aimed at poverty reduction. Monetary (e.g., household income or household consumption) and non-monetary (e.g., multiple poverty indicators, wealth index based on assets) approaches are used to measure poverty (27,28).

Worldwide, the proportion of people living on less than $1.25 a day has dropped from 47% in 1990 to 24% in 2008; therefore, the first target of MDG1 has been met (13). However, some places have reached MDG1 faster than others (Figure 1). Slow progress has occurred in sub-Saharan Africa and in southern Asia where only 20% to 35% of the countries are expected to achieve the MDG1 poverty reduction target by 2015.

Discussions about ways to assess MDG progress have continued, especially in those countries whose initial conditions were at a very low state (29). For example, most sub-Saharan Africa regions started with highest levels of poverty or mortality in comparison with the rest of the world, implying a greater challenge to meet goals. Although most extremely poor

countries might not succeed in halving poverty or meeting other MDG, some have reduced poverty levels faster than at any other time (30,31).

Child survival

Children are highly dependent on their environment during the first few years of life (i.e., parents, caretakers, health system). It is a time when they experience rapid brain growth and acquire skills and learning (32). Child survival statistics are an indicator of human rights, social development, and health care (33,34). They provide crucial information for mobilizing resources to improve the environment for the well-being of children. The Convention on Rights of the Child explicitly states that all children have the right to life, and nations have the obligation to ensure this commitment (35).

Approximately 90% of all deaths that occur before the age of 14 happen before the age of five (36). The under-five mortality rate is used as a summary health indicator to assess child health and survival. It is commonly subdivided into neonatal (< 28 days of life), infant (< 1 year) and childhood (from 1 to 4 years) mortality rates. Neonatal mortality is strongly associated with accessibility, availability, and quality of health care services (37,38). Infant and childhood mortality is related to socio-economic development (39). Under-five mortality is the target of the fourth MDG.

Epidemiology and millennium progress

The objective of MDG4 is to reduce the under five-mortality rate (U5MR) and the infant mortality rate (IMR) by two-thirds between 1990 and 2015. This two-third target is approximately the portion of child deaths that could be prevented in low- and middle-income settings by scaling-up affordable interventions (40).

About 205 million children worldwide died before the age of five between 1990 and 2011. Fifty percent of those deaths occurred between 1990 and 1998. The U5MR has declined over the decades from 11.9 million in 1990, to 9.3 million in 2000, and to 6.9 million in 2011 (14). More than 80% of these deaths are concentrated in two regions: sub-Saharan Africa and southern Asia. The reduction of deaths dropped the U5MR from 87 per 1000 live births in 1990 to 51 deaths per 1000 in 2011. One-third of world's countries had rates higher than the global average in 2011. Almost 90% of these countries are located in Africa, where the highest rate (187 deaths per 1000 live births) occurred in Sierra Leone in 2011.

The U5MR experienced a faster decline from 2000 to 2011 than during the first decade of the MDG (30% vs. 16%). These figures are still insufficient to reach MDG4, for which an annual average rate reduction (AARR) of at least 4.4%, as opposed to the current AARR of 2.2%, would be needed (15). Less than one-fifth of all countries might achieve MDG4 by 2015. Of the 75 countries that account for more than 95% of the global child deaths under age five, 23 are on track toward MDG4. These countries are part of

the continued surveillance performed by the Countdown to 2015 initiative, which seeks to enhance coverage of effective interventions, promote equity, and support national commitments to improve child and maternal health (41).

Causes of child deaths: the newborn challenge
Almost two-thirds of child deaths in LMIC are attributable to infectious diseases (42). Pneumonia, diarrhea, and malaria account for 36% of under-five deaths. In countries with high mortality, such as in Africa, 4 out of 10 deaths are attributable to these deaths conditions (43,44). Nevertheless, deaths from the same conditions were higher in the past, and a 4% annual reduction in diarrhea and a 3% annual reduction in pneumonia have been observed between 2000 and 2010 (44). In one-fifth of all child deaths, the underlying cause was malnutrition (45).

A drop in mortality after the first month of life has been achieved during the 1980s. After 1990, progress in the reduction of child mortality has continued. However slow progress has been made in improving newborn survival (37). Neonatal deaths declined from 4.4 to 2.9 million between 1990 and 2011. Two-fifths of all under-five deaths occur during the first 28 days of life. Approximately 75% of all neonatal deaths happen during the first week, and about 50% during the first day (46). Ten countries are responsible for 65% of all neonatal deaths worldwide: four are in Africa (Nigeria, Ethiopia, Congo, and Tanzania) and the rest in Asia (India, Pakistan, China, Bangladesh, Indonesia, and Afghanistan) (44). Almost three-quarters of those deaths are due to preterm birth complications, sepsis, and intrapartum-related conditions (42). More than 90% of these deaths are in Countdown countries. Worldwide the AARR of 2.1% between 2000 and 2010 in the neonatal period is still low to make progress toward MDG4 (47,48).

The effect of social inequalities on MDG

Certain population groups have less social advantages than others, and these disproportions affect outcomes in life. Most health outcomes for example, are worse for individuals who have greater socio-economic disadvantages than others (49). These differences are called social inequalities in the field of health (50). However, health differences do not only apply to wealth. Depending on outcome, available data, and public priorities, such inequalities may also be found in other social aspects including gender, age, ethnicity, race, education, occupation, or geography, generally summed up as socio-economic position (SEP) (51-53). A female newborn in Bangladesh has less chance to survive there than a male newborn. In Vietnam neonatal mortality is an invisible public health problem among minority ethnic groups (54). In Estonia, despite a great reduction, infant mortality is still higher in mothers

with low education than in mothers with high education (55). The Commission of Social Determinants of Health is a global network that assesses the impact of reducing social inequalities (inequities) on health outcomes (56).

Tackling social inequalities is a key issue for the MDG (57-59). Of the eight MDG, one (MDG3) explicitly addresses improving equity (unfair social inequalities). However, the assessment of inequality is implied in the remaining MDG. For example, the number of poor people is higher in rural than in urban populations. In LMIC underweight children are almost three times more prevalent among poor than among rich children. Primary school attendance is 1.4 times higher in wealthy families than in poor families. The U5MR is three times greater in children born to mothers with low education than to mothers with high education (32,60). Moreover, in excess of 80% of households without access to safe drinking water are rural (61).

An intervention may introduce social inequalities during the scale-up process (62), a situation historically recognized as the 'inverse care law', whereby less medical care is available for those who need it most (63). Thus, although the US is a rich nation with advanced medical technology, infant mortality is 54% higher among black than among white infants. The *inverse equity hypothesis*, which shares similarities with the inverse care law, focused attention on the trend toward widening inequalities once an intervention is underway (64). Studies have found that skilled birth attendance is an intervention that does not universally provide coverage to the less advantaged, although rapid progress is being made to narrow inequalities (65-67).

MDG in Latin-America: progress, and challenges

With 47 countries and a population of 591 million, Latin America has an average HDI of 0.73, ranging from 0.45 in Haiti to 0.85 in Chile. The population in the region is young (37% below the age of 18), and more than three-quarters of the inhabitants live in cities (8). Despite having an HDI similar to more developed regions, the Latin-American subcontinent has the highest social inequalities in the world (68).

Progress on MDG is mixed in the area, with considerable differences among the countries (Table 2). Overall, progress has been made in poverty reduction, education, equality, child health, and safe water, but not with regard to maternal mortality, MDG5. Mexico will reach at least one target of the eight MDG. Haiti, on the other hand, has the lowest probability of reaching the MDG by 2015 (69).

Table 2. *Millennium development goal trends in Latin America and Caribbean*[a]

MDG target	1990	Last available data	2015 target
MDG1: < $1.25/day	12%	6% (2008)	6%
MDG2: Primary school enrolment	94%	95% (2010)	100%
MDG3: Gender disparity primary/secondary education	97/107[b]	97/108 (2010)	97 to 103[c]
MDG4[d]: Child mortality	54	23 (2012)	18
MDG5[d]: Maternal mortality, Latin America/Caribbean	130/280	72/190 (2010)	33/70
MDG6[e]: HIV incidence	0.04	0.03 (2010)	0.02
MDG7: Access to an improved water source	85%	94%	93%

[a] MDG report 2012 (13)
[b] Available for 1999
[c] Accepted target for gender parity index
[d] per 1000 live births
[e] per 100,000 inhabitants

Although there has been progress, Latin America and the Caribbean continue to face challenges in meeting the MDG. The region estimates that it will need economic growth of at least 2.9% to reduce poverty. However, beyond macroeconomic development; the region has the highest and most persistent income and social inequalities in the world—almost one-fifth greater than sub-Saharan Africa (70,71). These inequalities affect MDG targets. For example, poverty is lower in urban areas compared to rural areas. Despite low levels of malnutrition, it remains 2.6 higher in rural than in urban areas. More than 94% of the population of Latin America has access to safe drinking water, but the percentage is lower in rural and poor households (72). The expansion of immunization has reduced child mortality (73), but among the poorest and mothers with low education, child mortality is almost three times greater than among the wealthiest and best educated mothers. Evidence has suggested that national economic growth in Latin America improves health for all when inequalities are narrowed (74).

MDG in Nicaragua: Goal 1 and Goal 4

Nicaragua is a country with 5 million inhabitants and an HDI of 0.59, located at the Central American isthmus (9). The population structure typical of most LMIC, is predominantly young (49% under age 19). It is divided into three regions: Pacific, Central, and Caribbean. Spanish is the official language, but in the Caribbean region English and minority ethnic languages

are also spoken. The capital of Managua in the pacific region has a concentration of one-quarter of Nicaraguan population. Because the country is located in the tropical zone, there is a wet season from May to November, and a dry season from December to April.

Nicaragua was ruled by a dictatorship between 1933 and 1979. It was a period of great inequality with one-third of the health resources allocated to the capital — where only 25% of the population lived (75). The years after the Sandinista revolution of 1979 were characterized by low economic growth but increased provision of social services (e.g., education and health) targeted at the poor through a massive communitarian participation called the *brigadistas* (76,77). Then a civil war during the mid- 1980s plus an economic embargo imposed by the US weakened the country's economy and affected social services, including health. By the end of 1987, 10% of the national budget was allocated to health service — but almost 40% was allocated to the military (78). Unfortunately, due o its location, Nicaragua is also prone to natural disasters (earthquakes, hurricanes, volcanic eruptions). Between 1990 and 2009 alone, $2.7 billion was lost to natural calamities (79).

Nicaragua is one of the signatory nations to the MDG. However, since it is a poor country, Nicaragua's data in tracking the MDG is uneven. The estimated under-reporting in counting deaths was 39% in 2009 for the civil registration system (80).

It is estimated that Nicaragua will not achieve all of the MDG by 2015, but progress (even accelerated progress) in some areas has been made (31). Extreme poverty has declined from 18.3% to 11.9% between 1993 and 2005 (81). Projections indicate that MGD1 is likely to be achieved by 2015. However, this overall decline in poverty is not always accompanied by a reduction in inequalities. The poverty in Nicaragua is more than twice as great in rural than in urban areas, and is higher in the Caribbean region than in the Pacific region. National plans to reduce poverty focus on improving income through the implementation of social programs, targeted at the poorest (82). The Zero Hunger program provides poor families with farm animals (cows, pigs, and chickens), arranges microfinances loans at low interest, and conducts seed programs to improve food security.

Reduction in child mortality has shown progress, but challenges have impeded further advances. From 1990 to 2011, the U5MR dropped from 63.9 to 29.1 deaths per 1000 live births, a 55.4% reduction. This child survival improvement had been initiated in the 1980s, when an expansion of health communitarian strategies targeted interventions to improve health and education of poor women and children — an effort recognized by UNESCO (83).

Child mortality has maintained an AARR of 4.0% from 1990 to 2011. But the reduction was faster during the first decade than from 2000 to 2010 (5.0% vs. 3.0%). This was attributed to a decline in mortality from infectious diseases that had a greater impact on the survival of those in the post-

neonatal and childhood age group. The neonatal mortality rate has declined from 22.4 in 1990 to 13 in 2011. However, in 1990 approximately 30% of under-five deaths were neonatal, a figure that has risen to 45% in 2001 (23,84). Social inequalities of mortality are also a large barrier to survival rates. The U5MR is lower in urban areas, among mothers with greater educational level or in rich families. Under these circumstances the country is currently not on track toward reaching MDG4.

Interventions to help reduce poverty and improve child survival in low-income countries

Poverty
Countries devise plans at the national level to combat poverty and promote economic growth. Every year, these anti-poverty strategies are presented in a "Poverty Reduction Strategy Paper" that is required of its members by the International Monetary Fund and the World Bank to support the fight against poverty in LMIC (85). Most of the help provided by outside agencies comes in the form of loans.

Although governments run anti-poverty programs, there are few evidence-based evaluations that have measured the impact of these programs. For example, Innovation for Poverty Action (IPA) is an initiative that implements interventions in LMIC from Latin America, to Africa, and to Asia using randomized controlled trials to reduce poverty by addressing in health, education, and employment (86). If a program proves to have a benefit, the next step is to scale it up.

Examples of interventions with a proven positive effect:

- Deworm the world initiative: 25% of dewormed children had less days of school absence than the control group (no participation).
- Remedial education: Working outside the classroom improves the grades of students with low classroom performance.
- Incentives for vaccines: High vaccination rates in children are achieved when parents receive a small non-cash incentive in return.
- Investment vouchers: Providing farmers with funds to buy fertilizer at harvest time increases income.
- Free mosquito netting: Distributing insecticide-treated bed nets reduce the incidence of malaria especially in pregnant women.
- Chlorine dispensers: Chlorine dispensers at water sources improve health for less than $0.5 a year.

- Reminders to save: Sending reminders via SMS increase savings and financial goals among a bank's clients.

The Millennium Village is another example of how affordable and sustainable programs that help reduce poverty and hunger may be implemented at the local level (87). Impact is measured through non-randomized evaluation designs (e.g., before and after). Among the most common programs millennium villages have are:
- Increased food production
- Malaria control
- Village clinics
- Construction of safe drinking water sources
- Empower villagers to develop capacity-building
- Introduce diversified agriculture
- Improve clean water and promote health
- Strengthen partnerships at the village level

Child survival

Up to 63% of child deaths and 73% of neonatal deaths can be averted annually if life saving interventions have high coverage (> 90%) (40,88). Breastfeeding and oral rehydration therapy may prevent 30% of all under-five deaths in LMIC. With 14 low-cost and high coverage interventions in the neonatal period it is possible to eliminate almost 60% of deaths, even in settings with a high neonatal mortality rate (> 45 deaths per 1000 live births) (88). Studies have analyzed the impact of community interventions on the reduction of childhood mortality in Africa. The evidence is not conclusive, but it suggests that community health workers are an effective way of improving child survival in poor settings (89). Further, actions have been taken to ensure child survival by the family, the community, and the health system through an initiative called Integrated Management of Childhood Illness (IMCI). Affordable interventions are available for the management of childhood diseases that cause a high burden of deaths in LMIC. Improving the skills of health personnel or introducing better health practices in the family and the community are the main interventions used by IMCI (90). The IMCI initiative has also improved communications between health workers and caregivers, resulting in the early detection of disease in the child and enabling prompt treatment at a community health unit (91).

Demographic Surveillance: a tool for monitoring MDG

Timely high-quality data are needed to monitor the MDG. This favors high-income countries whose statistical systems track birth demographic and epidemiological dynamics. For example in Sweden, a "person number" or indi-

vidual ID serves for several purposes, but is mainly used to record demographic information (birth, socioeconomic status, migration, living conditions, and death). However, in poor places data from civil registrations are either incomplete or simply not collected, with the result that two-thirds of the population is invisible to the public agenda (92,93). In many LIMC the level of underreporting is negatively correlated with age, and children especially newborns are not included in the statistic registers (54). These limitations challenge researchers who wish to perform analyzes to convince policy makers to secure their country's data (94,95).

All the MDG have targets with relative quantitative indicators. In order to measure the targets, a numerator (defining the event or case) and a denominator (representing the population) are required. Four of the MDG (1,2,3, and 7) contain targets that can be collected from a national census that counts every person or national household surveys where a probabilistic sample is chosen. However, census or households surveys have difficulties linking data at the individual level. For the health-related millennium goals, the implementation of national reproductive surveys has served to generate relevant baseline data for child and maternal targets. Demographic health surveys and multiple indicator cluster surveys have filled in the gap with good data in these areas (96,97). The period for each survey is generally every five years, i.e., shorter than the census.

Other sources of data are the demographic surveillance sites (HDSS) (98). Basically a HDSS collects, analyzes, interprets, and evaluates demographic and epidemiological data about a population cohort. It is generally established in communities that represent a region of the country. There are approximately 45 HDSS around the world, under the supervision of the International Network for the Demographic Evaluation of Populations and Their Health (INDEPTH). Most HDSS are located in Africa and Asia (99) and the populations considered may vary between 50,000 and 200,000 people. Based on a probabilistic approach, a sample is selected and then a baseline measurement performed. Periodic routines collect vital events (births, deaths, and migration), background characteristics of residents, and housing conditions (Figure 2). The time interval between each data collection varies, depending on the outcome sought and the resources available. Most HDSS update information every three months (100).

HDSS has been seen as a opportunity for those at the local level to analyze MDG progress, monitor trends in social inequalities, evaluate the impact of interventions on the population, and establish an ongoing dialogue between evidence-based practice and policy (101,102).

Rationale of this study

Aggregated analysis of MDG progress cannot assure that it has been homogeneous at either the global or national level. Community data (e.g., census, survey, or surveillance) help to identify relevance of the effect of social inequalities on MDG in the public agenda of policymakers and stakeholders.

In poor contexts, the reduction of poverty and inequalities is likely possible. The initiative known as the Millennium Villages in Africa promises to be one example of success towards the achievement of MDG. However, evidence is scant.

This thesis focuses its analysis on the progress of selected MDG and community interventions from a perspective of social inequality. Figure 1 illustrates an overview of the studies performed.

Figure 1. Overview of the studies in this thesis
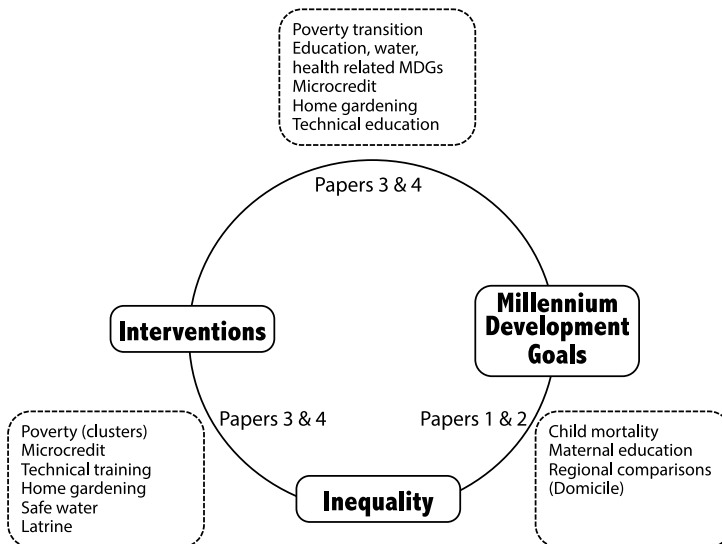
Aims

The overall aim of this thesis was to monitor selected MDG, assess barriers to achieving them, and evaluate forces driving their progress in typical Nicaraguan communities.

Specific aims:

Papers 1 and 2

1. Analyze the trends of under-five and neonatal mortality rates as indicators of MDG4, and the inequality gap by mother's education.

2. Compare the level and trend of under-five mortality in three Nicaraguan settings (urban, rural, and remote rural).

Papers 3 and 4

3. Measure and monitor the level of poverty (MDG1) and its transition in a remote rural community; describe a set of community interventions; and measure the impact on the reduction of the poverty.

4. Analyze the progress of a set of MDG in a remote rural community, and the spatial distribution of community interventions in that area.

Methods

Study setting

The data upon which this thesis is based derives from two Nicaraguan communities, the León municipality and Cuatro Santos. León is located close to the Pacific region of Nicaragua about 93 km from the capital of Managua and covers a territorial extension of 820 km^2 (Figure 2). It is divided into three sub-districts with a population of 174,051, about 80% of which is urban. Almost half of the residents of León are under age 18 (103). León has a teaching hospital, which is also referral hospital for the Pacific region, and each sub-district has a health centre and neighborhood health posts providing curative and preventive health services.

Cuatro Santos, on the other hand, is a mountainous rural province of 292 km^2. It consists of four municipalities situated 250 km to the northwest of the capital. Its population is estimated at 25,000 inhabitants. Primary health care services are provided by general practitioners and nurses. The closest hospital is about 130 km from the area.

The HDI of Cuatro Santos was 0.52 in 2002, whereas the León municipality had an HDI of 0.74 (104). Agriculture and raising livestock dominate the economy in the rural areas, while a labor market are typical of the urban areas.

Health and demographic surveillance site

An HDSS was established in León in 2003. It was built from a cluster-sampling framework begun in 1993. The estimated sample size of the baseline was 50,000 inhabitants representing 30% of the total population distributed in 50 clusters. A cluster was defined as a geographical area with a population of 700 to 1000 inhabitants. Two follow-ups were carried out in 2005 and one in 2008. In Cuatro Santos, the HDSS baseline was established in 2004 covering the total population of these municipalities. Follow-ups took place in 2007 and 2009.

Information in the HDSS was updated during follow-ups for each household and family member, and a unique ID allowed tracking them. Background data such as education, employment, vital events (deaths, births, and migration), and housing conditions (type of water, sanitation, floor and wall construction) were linked through the ID of each inhabitant and house. Birth histories of women in their reproductive years (15 to 49) recorded data on child survival.

Figure 2. The León and Cuatro Santos study areas (shaded areas) in Nicaragua
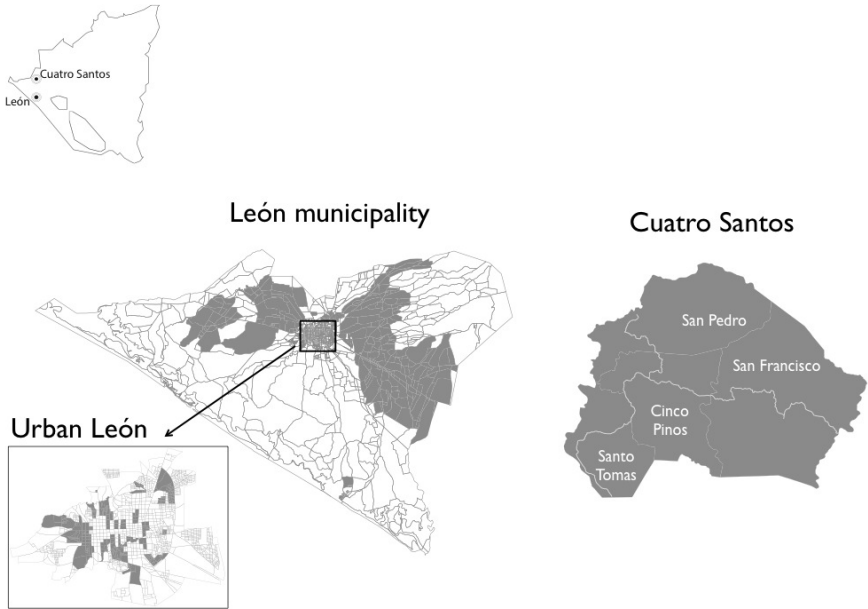
Study designs and participants

The four papers in this thesis are based on data from both HDSS (León and Cuatro Santos). Table 3 describes the study design and other related information. In papers 1 and 2 retrospective surveys recorded the full birth histories of women of reproductive age (15 to 49 years). Birth and survival status were obtained for every child.

In León, four reproductive surveys were performed: 1993, 2002, two in 2005, and one in 2008. All were carried out in the same study clusters, and records were linked to the HDSS baseline. In Cuatro Santos, retrospective surveys were made in 2004, 2007, and 2009. Using maternal IDs, the birth histories were updated during data collection. A total of 49,972 live births and 2,653 under-five deaths occurred in León between 1970 and 2005. In total, 48% of live births and 27% of under-five deaths were reported from 1990 to 2005. In Cuatro Santos, 12,879 live births and 408 under-five deaths occurred from 1990 to 2008. Verbal autopsies (VA) were used to ascertain cause of death.

Papers 3 and 4 utilized data from baseline and follow-up in Cuatro Santos. A total of 4,451 and 5,037 households were interviewed in 2004 and 2009, and a panel of 3,852 households was set up to represent the households present in both years.

Data collection

For papers 1 and 2, female field workers conducted interviews with mothers in a private setting. Supervisors carried out quality control during fieldwork. If an error was found in the questionnaire, the field worker returned for a re-interview. Data collection was facilitated by the use of a local events calendar to approximate the dates of births and deaths. Age of the mother at delivery, parity, and domicile was also obtained. Birth histories of mothers who migrated from the study area were not updated, but such histories were collected from mothers who migrated into the area.

The HDSS recorded data for those child deaths that occurred to mothers residing in the study area. A VA was used to ascertain the cause of death in the study area. This standard VA was developed by WHO and INDEPTH and was translated from English to Spanish and adapted to the context (105). Three physicians in León and two in Cuatro Santos read the VAs and determined the most probable cause of death using the International Classification of Diseases, 10th edition. One VA for neonatal and another for deaths that occurred between 28 days and 59 months of life were utilized.

Table 3. *Research methods utilized in papers 1 to 4*

Papers	Study area	Study design and period	Sample Size	Exposure	Outcome
Paper 1	León municipality	Retrospective survey, 1970 to 2005	49,972 births	Maternal education	Under-five mortality; neonatal mortality
Paper 2	León municipality and Cuatro Santos	Retrospective survey, 1990 to 2005 in León and 1990 to 2008 in Cuatro Santos	24,385 births in León	Maternal education	Under-five mortality
			12,879 births in Cuatro Santos	Domicile (urban León, rural León, and Cuatro Santos)	
		Verbal autopsies	59 in León, and 39 in Cuatro Santos		Under-five mortality
Paper 3	Cuatro Santos	Household cohort, 2004-2009	4,451 households (2004)-HDSS baseline; and 5,037 households (2009)-follow-up	Microcredit, home garden, and technical education	Poverty transition (poor to non-poor)
		Panel of poor households, 2004 to 2009	3,852 households		
Paper 4	Cuatro Santos	Descriptive, 2004 to 2009	4,451 households (2004), baseline and 5,037 households (2009), follow-up	Poverty clusters	Microcredit, home gardening, and technical training
					Education, gender equity education, selected health MDG

In papers 3 and 4, data on housing conditions, literacy, and reproductive issues from the HDSS in Cuatro Santos in 2004 and 2009 were used. By 2009 a questionnaire asking for participation in interventions related to installation of piped drinking water and latrines, microcredit, participation in home gardens, and telecommunications was added during the HDSS update of all households. The spatial position of every household in the HDSS was determined with Geographical Position System technology.

Community interventions in Cuatro Santos

In October 1998, Hurricane Mitch struck Nicaragua, affecting 867,752 people (one-fifth of the population), severely damaging the country's infrastructure (roads, agriculture, homes) and economy, and killing 3,045 people (106). The region mostly affected was the northern part, where Cuatro Santos is located. In the 14 years since, the local government and non-governmental organizations (NGOs) have launched a series of interventions in microfinance, home gardening, technical training, telecommunications, Internet, housing construction, school breakfasts, safe drinking water, and sanitation (107).

Microcredit

A small-scale microcredit project began in 1998, just before Hurricane Mitch struck. Since then, two NGO microfinance banks called CEPRODEL and the NGO APRODESE began to provide loans in Cuatro Santos. CEPRODEL loans varied from US $1,000 to US $5,000; APRODESE loans were up to US $250. The main purpose of the loans was to finance agricultural and industrial activities. It is estimated that about US $5 million was invested in microcredit programs in Cuatro Santos.

Home gardening

Home gardens were encouraged in the area through a participatory process of farm planning. The main products for cultivation were vegetables, fruits, cassava, corn, and beans. Most of the harvest was for consumption, but some could be sold to pay for uniforms and school supplies for the children. An estimated of 800 families have participated in the seed project bank (Elmer Zelaya Blandón, personal communication, September 2012).

Technical training

An educational center was established in Cuatro Santos offering courses free of charge. The classes, which ran from 700 to 1,300 hours, were certified by National Technological Institute (INATEC). According to INATEC 1,600 women and men have been trained in carpentry, soldering, electricity, computer science, baking, agriculture, and solar energy, between 1998 and 2012. Some students who graduated also received a small credit with which to purchase basic equipment and start their own business, and the best students were given scholarships to study at the university.

Safe drinking water

Local governments and NGOs have provided safe drinking water to approximately 27% of the houses that had not such access. However, since water systems are driven by pumps that require electricity, which in turn is only available along the main road, remote households could be benefit from the

safe water initiative. However, recent actions are giving priority to communities further than 5 km from the man road by using gravity or renewable energy systems.

School breakfasts

A food intervention was implemented to attract children to enter the public school system. It focused mainly on primary schools and consisted of a glass of milk fortified with vitamins A and D, and a cookie made of soy. The program initially began in a village school in Cuatro Santos. After three weeks, 30 children who had dropped out returned to school. In 2002, two municipalities in Cuatro Santos adopted this program in their schools. By 2007, the Ministry of Education had instituted student breakfasts in all public schools in Nicaragua, an action that the National Parliament made into law.

Operationalization of variables

Maternal education was categorized in two groups: mothers with no formal education (illiterate or had not completed primary school), and mothers with formal education (completed primary school or beyond). Primary school was considered completed when a person finished grade 6 or above. These categories were used in other studies in this area.

The education of the neighbor was based on the median of the number of years of education of the resident mothers, and it was categorized in two groups: formal and no formal.

Parity was grouped into three levels: mothers with one live birth, mothers from two to four live births, and mothers with more than four live births.

Place of delivery was categorized as hospital, health centre, private clinic, home, or other place.

Attendant at delivery was classified as physician, nurse, midwife, or other person.

Skilled birth attendance was defined when a physician or nurse attended the delivery.

Poverty was measured using the Unsatisfied Basic Needs Index. This index is composed of four components: 1) information on housing conditions (i.e., wall and floor construction), 2) access to water and latrine, 3) school enrollment of children, and 4) education of head of family and dependency ratio (i.e., number of people in the family who are < 15 or > 65, divided by the

number of people between 15 and 65). Each component received a score of one if unsatisfied (Table 4). The total sum varied between 0 and 4. Non-poor households were those with 0 or 1 unsatisfied needs, poor households had 2 and 3 unsatisfied needs, and extremely poor households had 4 unsatisfied basic needs.

Poverty transition was defined as the change from one state of poverty in year zero to another poverty status in a different year.

Table 4. *Unsatisfied basic needs conditions by each poverty component*

Component	Unsatisfied need
Housing conditions	Wall is made of wood, cartons, plastic *and* floor is earthen
Access to water and latrine	Water is through rivers, wells, or bought in barrels *and* no latrine
School enrollment	Children ages 7 to 14 not attending school
Education of head of family and dependency ratio	Head of family is illiterate *or* did not complete primary school *and* dependency ratio > 2

Microcredit participation was defined as the enrollment of at least one family member in a microcredit loan.

Home gardening was defined as participation in the cultivation of vegetables or fruits in home gardens.

Technical training (or technical education) was defined as the involvement of at least one family member between 18 and 40 years of age in a technical education program such as computer science, carpentry, cooking, or soldering.

Household size was defined as the number of family members residing in the household at the time of the interview.

Migration was considered when at least one family member ages 18 to 65 migrated for economic reasons during the study period and outside the study area.

Children attending primary school were defined as any child between 7 and 12 years of age in the school at the moment of the interview.

Literacy rate between 15 and 24 is the proportion of people in that age group with some education, excluding those who are illiterate.

Drinking water and sanitation were defined as those households having piped drinking water or either latrine or toilet accessibility.

Statistical analysis

In paper 1, neonatal, infant, and under-five mortality rates were measured from 1970 to 2005. To reduce random variation in the time series of mortality, rates were smoothed using 3 years moving averages. The U5MR trend was stratified by domicile (urban vs. rural). The place of delivery and attendance at birth between 2003 and 2005 was measured and stratified by domicile, and tested using Chi^2. Significant differences were assessed when $p < 0.05$. Cox regression was used to measure inequality in neonatal and under-five mortality by maternal education and reported as a hazard ratio and its 95% CI over the course of three time periods from 1970 to 2005. The model was adjusted by parity and domicile.

In Paper 2 the U5MR and AARR of the U5MR were compared in urban León, rural León, and Cuatro Santos between 1990 and 2008 with smoothed rates. The projected U5MR by 2015 in each setting was calculated in two scenarios: the first considered an AARR of 4.4% (the required to achieve MDG4), and second used the last observed AARR. A Cox regression with robust standard errors was conducted between the level of education of the mother relative to the level of education of the neighborhood and under-five mortality for three time periods: 1990 to 1994, 1995 to 1999, and 2000 to 2005. The model was adjusted for maternal age, parity, and domicile (urban León, rural León, and Cuatro Santos). The proportion of deaths by cause was measured for all deaths that occurred after the HDSS baseline.

In paper 3, poverty levels were measured in 2004 and 2009. The amount of participation in the interventions was compared between the non-poor, poor, and extremely poor in 2004 and 2009. Significant differences were considered when the 95% CI overlapped.

The association between interventions and the poverty transitions was assessed using propensity score (PS) models to balance the distribution of confounders between the intervention and the control group. For each of the interventions (microcredit, home gardening, and technical training) PS values were computed using logistic regression. The predictors for the PS were the others two interventions as long as the sex head of household, age of head of household, and presence of at least one person between 15 and 65 years of age who out-migrated from the study area to another place for economic reasons (i.e., employment). Once the PS was computed, the intervention and the PS values were then included in a multivariate model where the transition from poor to non-poor was the outcome. The prevalence ratio (PR) with its 95% CI measured the association between participation in the intervention and the poverty transition (from poor to non-poor). The c-statistic and the Brier's score were used to assess the predictive capacity of the model. Values for the c-statistic > 0.80 or a Brier's score < 0.25 were considered good.

For paper 4, we compared selected MDG obtained from the HDSS in Cuatro Santos in 2004 and 2009. Poverty, education, educational gender equality, under-five mortality, skilled birth attendance, adolescent birth rate, access to safe drinking water, and sanitation were target indicators. The level of participation in interventions was assessed. Therefore, we computed the proportion cumulative interventions in 2004 and 2009, so that by 2009 the total number of interventions is included (some interventions happened before the HDSS baseline).

We conducted a spatial cluster analysis using a spatial scan statistics test for poverty in 2004 and 2009, and for the total number of interventions a house had participated in. Interventions included were safe drinking water, latrines, microcredit, home gardening, and technical training. In this geographical analysis a high cluster and a low cluster were derived. High clusters occurred when the observed frequency of the event (poverty or intervention) is higher than expected; conversely, low clusters occur when that frequency is lower than the expected. If there is no difference between the observed and the expected frequencies, there is no clustering. Significant spatial clustering was considered when the *p*-value was less than 5%.

A multinomial logistic regression was performed in order to examine the odds of single interventions on the poverty clusters. These clusters were those identified using the spatial technique. The independent variables were cumulative participation in the interventions in 2004 and 2009. The dependent variable was coded as high cluster, low cluster, and no cluster. No cluster was considered the category of reference. The OR with its 95% CI were used to measure the odds of receiving the single intervention. The association was positive when the OR > 1 (meaning a high odds of receiving the intervention), and negative when OR < 1 (meaning a low odds of receiving the intervention). Significance was assessed when 1 was not included in the 95% CI of the OR.

All data used in this thesis were stored in Microsoft Access 2000. The statistical analysis was performed with SPSS 20.0 and Stata 12.0. SatScan free software and ArcGIS 3.0 were used for the spatial analysis.

Ethics considerations

The Ethic Committee of the National University of León, Nicaragua, approved the HDSS in León and Cuatro Santos. During fieldwork, informed verbal consent was obtained from the head of household and from mothers interviewed. All participants were told they could discontinue the interview at any time and without having to give any reason. Meetings were held in the community to disseminate the results of the study.

Results

Child mortality and inequality: Papers 1 and 2

Progress toward MDG4

In León the U5MR rate dropped from 105 per 1000 live births to 28 per 1000 between 1990 and 2005. The IMR trend was almost the same as the U5MR. Neonatal mortality decreased, but after 1998 the neonatal mortality rate (NMR) increased from 10 per 1000 to 19 per 1000. In the early 1970s, neonatal deaths accounted for 45% of all under-five deaths; and from 2003 to 2005 it increased to 83%. Only 3% of all deliveries occurred at home, more so in rural (9.6%) than in urban areas (0.5%). Deliveries with skilled birth attendance were higher ($p < 0.01$) in the urban (99.4%) than rural areas (88%).

   The U5MR was higher in rural than in urban areas ($p = 0.01$). In 1993 the percentage of women with formal education was 37%, rising to 72% in 2002. The U5MR declined to 66% in the no formal education group and to 71% in the formal education group. Mothers with formal education had lower a U5MR than mothers with no formal education; in both groups the rate showed a reduction. The gap in neonatal and under-five mortality by maternal education (no formal education vs. formal education) was reduced between 1970 and 2005 (Figure 3a and 3b). The gap was pronounced during the period 1970–1981. However, between 1982 and 1993, the gap was very small for neonatal mortality and differences were not significant. For the period 1994–2005 the gap tended to increase, but significant differences were observed only in under-five mortality.

Figure 3. Neonatal (3a) and under-five (3b) mortality hazard ratios (HR 95% CI) in relation to educational level of the mother and time period
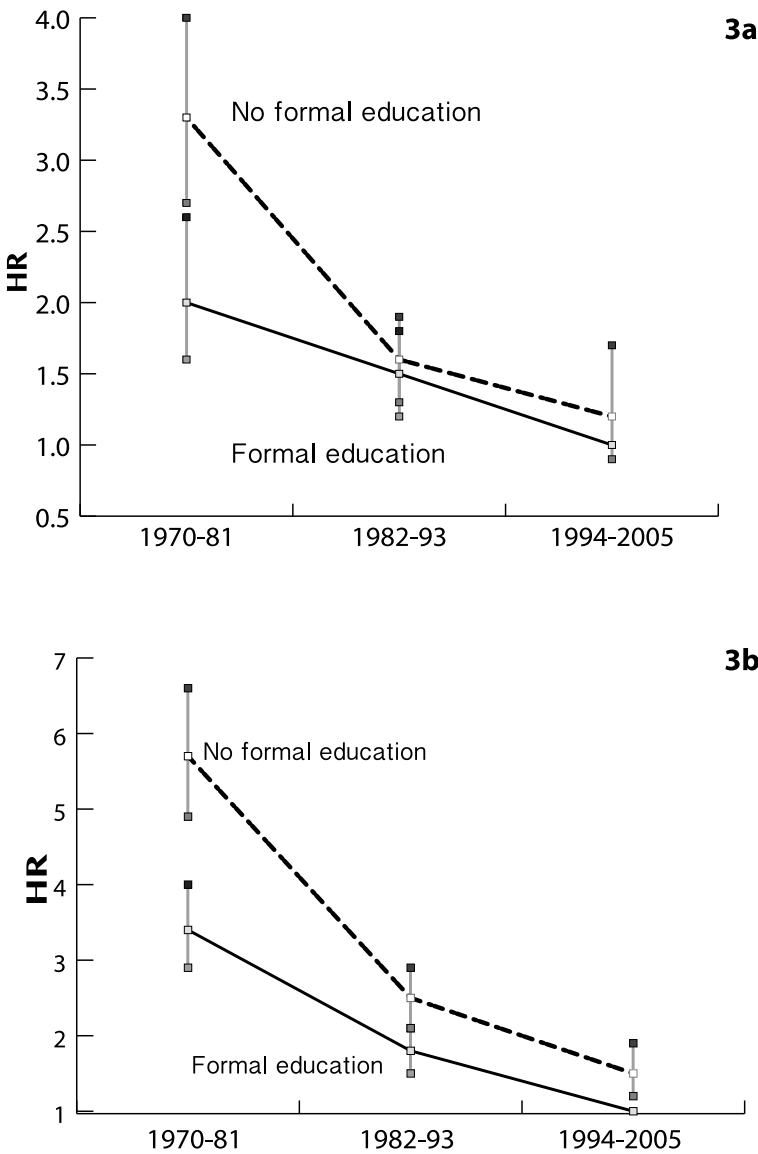
Comparing León and Cuatro Santos, urban León reduced its mortality by 60%, rural León by 45%, and Cuatro Santos by 36% between 1990 and 2005. Urban León showed the highest annual reduction (AARR = 7.1%), followed by rural León (AARR = 4.6%), and then Cuatro Santos (AARR = 3.8%) between 1990 and 2005. Rural mothers with no formal education re-

ported an AARR of 0.7%, the lowest percentage of any subgroup in the study (Figure 4). By 2015, the expected U5MR using an AARR = 4.4% will be: 16.2 per 1000 in urban León, 18.4 per 1000 in rural León, and 13.7 per 1000 in Cuatro Santos. On the other hand, the expected U5MR by 2015 based on the observed AARR indicates that the three settings will meet the goal, but urban León will reach it before that deadline.

Between 1990 and 1994, the highest risk of mortality occurred among mothers with no formal education whose neighbors also had no formal education (HR = 1.7; 95% CI, 1.2–2.5), while the lowest risk was among mothers with formal education residing among neighbors with formal education (HR = 1.1; 95% CI, 0.9–1.5) (Table 5). During the two time periods (1995 to 1999 and 2000 to 2005), the association between maternal education relative to the education in the neighborhood was not significant.

Table 5. *Maternal education and the relative education in neighborhood on under-five mortality in León and Cuatro Santos, Nicaragua, 1990 to 2005*

Education (mother–neighborhood)	Hazard Ratio[a]	95% CI
1990–1994		
Formal–Formal	1.1	0.9–1.5
Formal–No formal	1.6	1.1–2.3
No formal–Formal	1.4	1.07–2.0
No formal–No formal	1.7	1.2–2.5
1995–1999		
Formal–Formal	0.7	0.5–1.06
Formal–No formal	0.9	0.5–1.4
No formal–Formal	1.2	0.7–1.9
No formal–No formal	1.2	0.8–1.7
2000–2005		
Formal–Formal	1	
Formal–No formal	1.1	0.7–1.7
No formal–Formal	1.2	0.7–2.1
No formal–No formal	1.4	0.9–2.2

[a] Adjusted for domicile (urban León, rural León, and Cuatro Santos), maternal age, and parity

Figure 4. Under age five mortality rate and annual average reduction rate (AARR) by maternal education and time period in León (urban and rural) and Cuatro Santos, Nicaragua, 1990 to 2008, expressed as three-year moving average
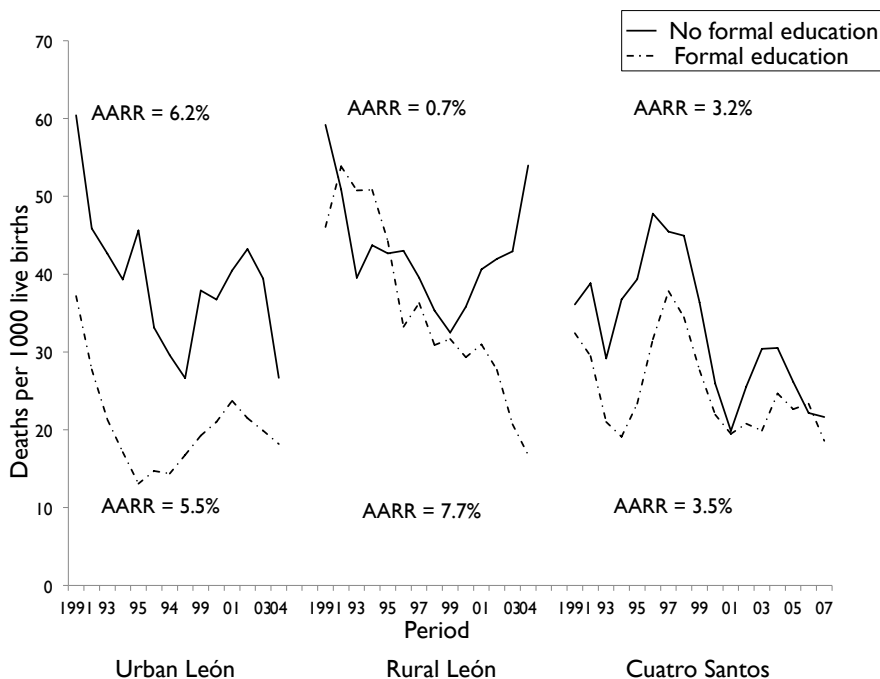

Causes of child deaths

A total of 98 under-five VAs were performed, 59 in León and 39 in Cuatro Santos (Figure 5). In León, 3 VAs were refused by interviewees and 9 could not be conducted because the parents had migrated away from the area. In Cuatro Santos, only one VA could no be performed due to out-migration. Neonatal mortality was the primary cause of death in both settings. The percentage was greater in León (59%) than in Cuatro Santos (40%). Sixty percent of the deaths occurred in a hospital, 5% in a health centre, and 35% at home. Respiratory distress was the main cause of neonatal death in León and Cuatro Santos. Pneumonia and diarrhea were the first and second causes of death after the first month.

For those deaths that occurred after the first month but before five years of age, most deaths in León were in the hospital (83%). In Cuatro Santos 58% of the deaths in the same period took place at home or somewhere other than hospital or health centre. Diarrhea and pneumonia accounted for 66% of the deaths of children under age 5 in León after the first month of life and 45% in Cuatro Santos.

Figure 5. Combined causes of under-five (n = 98) and neonatal (n = 51) deaths in León (2003 to 2007) and Cuatro Santos (2004 to 2008) (figures combined), Nicaragua
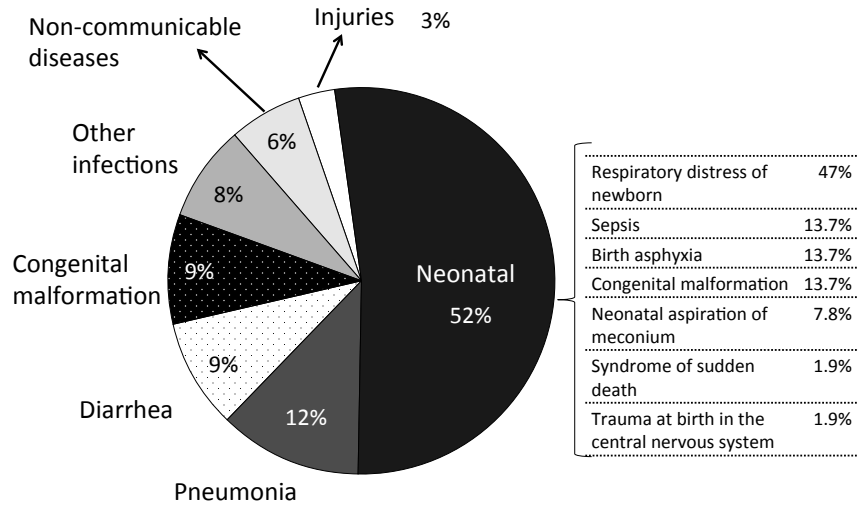

Community actions and MDG progress: Papers 3 and 4

Interventions and MDG1

The level of poverty and extreme poverty declined by 13% and 5% respectively, in Cuatro Santos between 2004 and 2009. Of the 3,852 households in the cohort from baseline to follow-up, approximately two-thirds transitioned out of poverty. In the group of non-poor households in 2004, 83.6% remained non-poor by 2009, whereas 33.4% of poor households and 13.7% of extremely poor households transitioned to non-poor status between 2004 and 2009 (Figure 6).

Figure 6. Panel of households that transitioned out of poverty from 2004 to 2009 (n = 3,852)
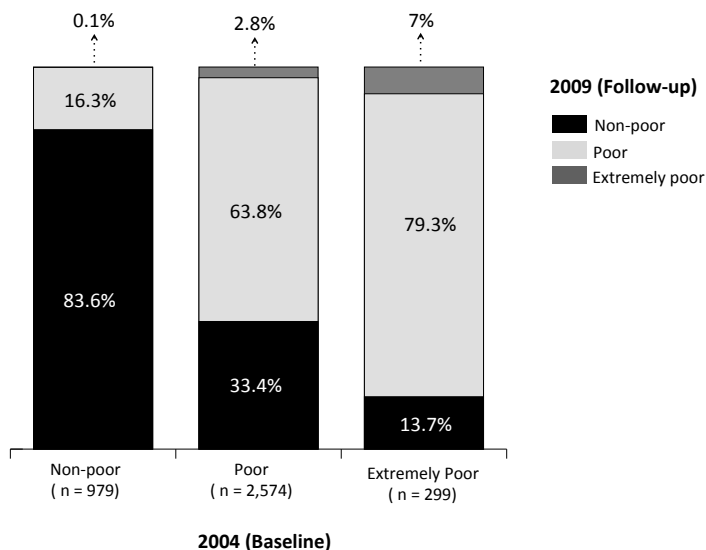
Interventions with regard to safe water, latrines, microcredit, home garden-ing, and technical training increased since 1990, although most interventions were implemented between 2005 and 2009. In analyzing the distribution of these interventions by poverty level, non-poor people tended to be given more microcredit assistance (Table 6). However, no significant differences were observed in the distribution of home gardening interventions. In 2004, technical training was unequal, however, by 2009 differences were not sig-nificant.

Table 6. *Distribution of microcredit, home gardens, and technical training interven-tions rate per 1000 by poverty level, Cuatro Santos, Nicaragua, 2004 and 2009*

Program	2004		2009	
Microcredit	Population ages 15–65		Population ages 15–65	
Non-poor	3,044	2.3 (7) [1.0–4.9][a]	6,229	*27.9 (174) [24.0–32.4]*
Poor and extremely poor	9,039	1.2 (11) [0.6–2.2]	8,439	*14.8 (125) [12.3–17.6]*
Home gardens	Households			
Non-poor	1,095	6.4 (7) [2.8–13.7]	2,111	36.0 (76) [28.6–45.0]
Poor and extremely poor	3,356	6.9 (23) [4.4–10.4]	2,926	40.0 (117) [33.3–47.8]
Technical training	Population ages 18–40			
Non-poor	1,831	*12.6 (23) [8.1–19.1]*	3,514	14.2 (50) [10.6–18.8]
Poor and extremely poor	5,228	*2.7 (14) [1.5–4.6]*	4,980	13.8 (69) [10.8–17.5]

[a]Data are presented as rate (n) with 95% CI. Italics indicate significant differences

Microcredit (APR = 1.28; 95% CI, 1.14–1.46), home gardening (APR = 1.20; 95% CI 1.02–1.41), and technical training (APR = 1.27; 95% CI, 1.10–1.46) were associated to the transition from poor to non-poor during the period of the study (Table 7)

Table 7. Estimated association between interventions and poverty transition, Cuatro Santos, Nicaragua, 2004 to 2009 (n = 2,574)

| Intervention	Model poor to non-poor APR[a] (95%CI)	c-statistic	Brier's score for each propensity score model
Microcredit (yes)	1.29 (1.14–1.46)	0.61	0.16
Technical training (yes)	1.20 (1.02–1.41)	0.66	0.09
Home gardening (yes)	1.27 (1.10–1.46)	0.61	0.11

[a]APR: adjusted prevalence ratio

In the spatial analysis in 2004, we found a high cluster of poverty and three small clusters with lower risk of poverty. By 2009, only the high cluster of poverty remained in the same area (Figure 7). Same spatial analysis on interventions showed a large high cluster of intervention in 2004 (Figure 8). However, by 2009 high clusters had disappeared, as well as other small low clusters. A low cluster of interventions appeared in 2009. The multinomial analysis between each intervention and clusters of poverty indicated that technical training and safe water installations were positively associated (OR > 1) with clusters of low poverty in 2004, but technical training, home gardening, and latrines were negatively associated (OR < 1) in high clusters high poverty. The same analysis in 2009 showed that in low clusters of poverty all the interventions were positively associated except home gardening, and in high clusters of poverty microcredit, safe water, and latrines were negatively associated.

Other MDG in Cuatro Santos
We reported the trend of other MDG in Cuatro Santos by 2004 and 2009. For the MDG2, the enrollment of children of school age was 88% in both years. The literacy rate of people ages 15 to 24 increased from 93% in 2004 to 97% by 2009. MDG3, the gender parity index (girls vs. boys) showed that primary school enrollment there was not inequality gap, but in secondary education the gender parity index was 1.2 in 2004 and 1.3 in 2009. The adolescent birth rate declined from 61/1000 to 48/1000 in the same period. The percentage of people with access to piped drinking water increased from 18% to 28%. Access to toilets or latrines was 73% in 2004 and increased to 80% by 2009.

Figure 7. High and low clusters of poverty in Cuatro Santos, Nicaragua, 2004 (n = 3,843) and 2009 (n = 4,968)
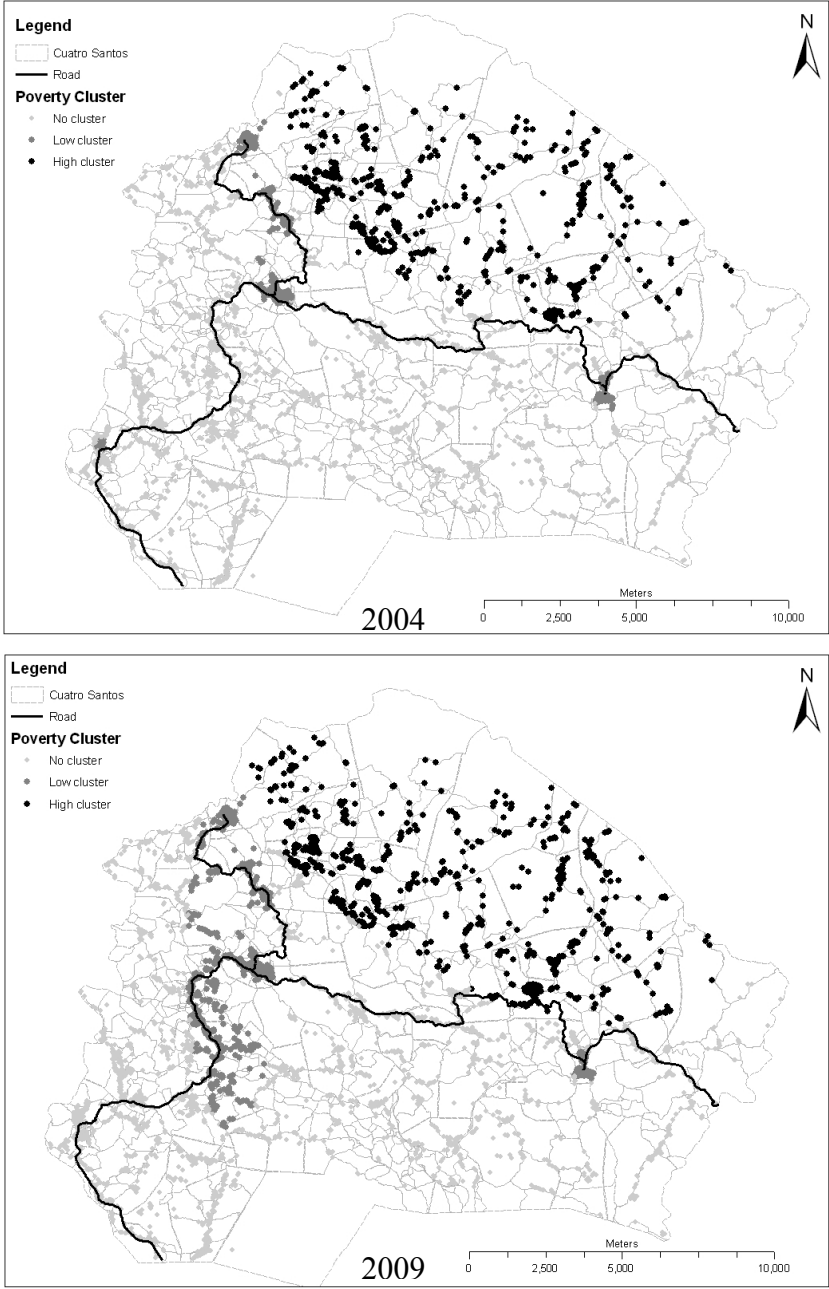
Figure 8. High and low clusters of any intervention in Cuatro Santos, Nicaragua, 2004 (n = 3,843) and 2009 (n = 4,968)
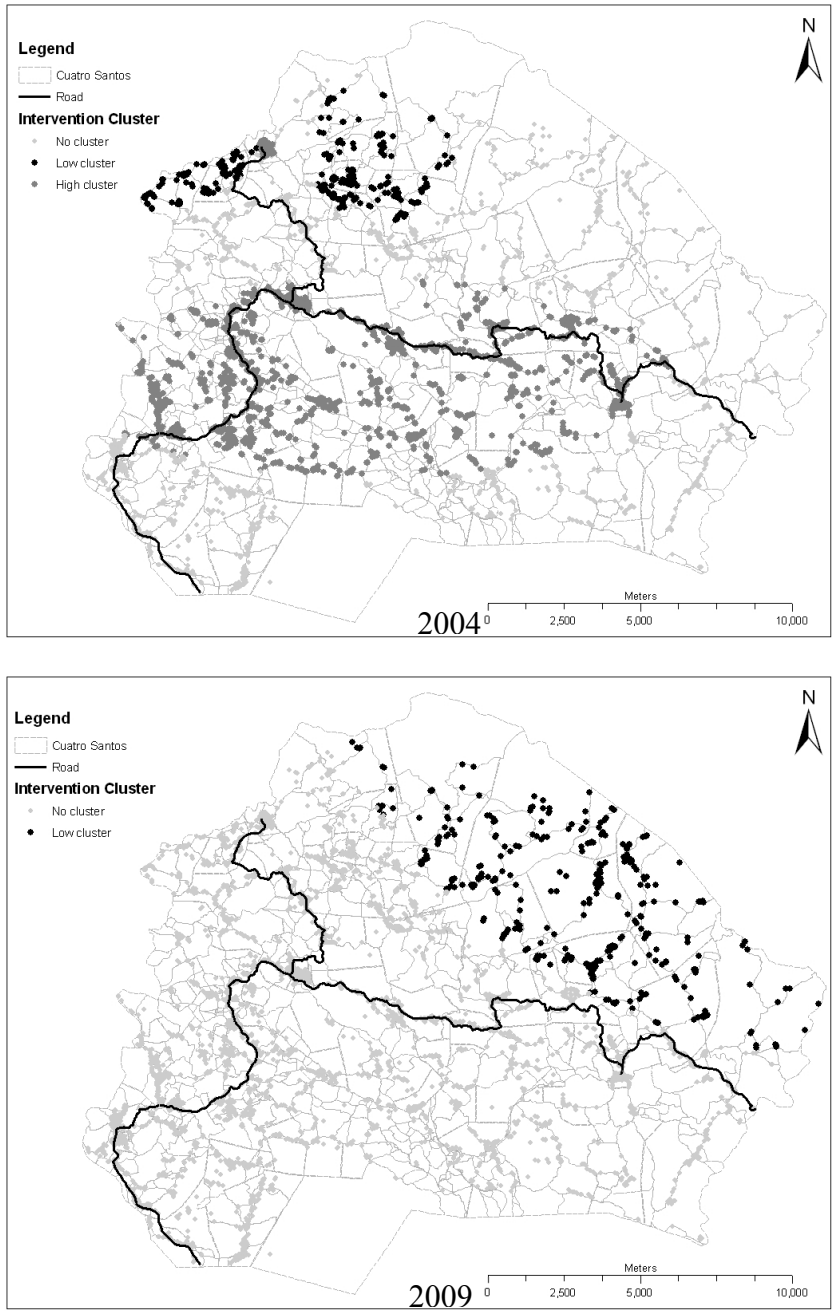
Discussion

The MDG4 progress

Under-five mortality reduction, newborn survival challenge

The decline of child mortality in Nicaragua is well known (108-110). Reductions were initiated even before the MDG, when the national political agenda focused on improving the health of socio-economically disadvantaged populations, such as women and children in remote rural areas (77,111,112). Decreasing mortality related to infectious diseases contributed greatly to increasing child survival.

In our study of the León municipality, this trend was also observed. Since 1997 child mortality has dropped to a level where most under-five deaths occur during the first month of life. This pattern is also found in other LMIC, suggesting that more emphasis on the health of newborns is needed to achieve MDG4 by 2015 (113,114). Newborn survival is greatly dependent on a country's health system. In León, most deliveries take place in hospitals and are attended by a physician. In the early 1990s an intervention was carried out in León's regional hospital that reduced neonatal mortality from 56/1000 to 11/1000 live births from baseline in 1985 to 1993 (115). The intervention involved weekly audits and introduction of educational and hygienic measures among the neonatology staff. On the community level, the NMR since 1985 has been reduced to 10/1000, although it has since increased.

Equitable child survival by maternal education

Social inequalities decelerate progress toward MDG4. Maternal education has been studied as one of the SEP indicators associated with child survival (116-120). Mothers with greater knowledge understand healthcare instructions, and are familiar with access to health services, and implement preventive measures to improve child health and survival (119). It is estimated that an increase of one year of maternal education will reduce child mortality by 9% (121)

Statistics from the Demographic Health Survey 2006–07 in Nicaragua report that illiterate mothers experience up to three times greater child mortality than mothers with some education (122). This gap is greater than that found by comparing child mortality between the lowest and the highest quintiles of wealth.

In the areas we studied, maternal education resulted in reductions in both neonatal and under-five mortality. According to the inverse equity hypothesis, the reduction of mortality would occurred first in groups of mothers with formal education and later in mothers with no formal education (64). However, this was not the case in the León municipality or in Cuatro Santos. Access to education especially for women has improved; for example, at the national level it is reported that the education of women who are of reproductive age increased from 33% in 1998 to 76% in 2006–2007. This progress enhances the opportunities to improve economic conditions and access to health services for women. Recently, a study found that countries with rapid expansion of life saving interventions were narrowing inequalities (67).

Despite the overall reduction showed in rural León to meet MDG4 by 2015, inequalities have widened. The AARR indicated that the child mortality rate among mothers with no formal education will make it impossible to achieve the millennium goal, perhaps suggesting that the inverse equity hypothesis is occurring in this area.

We found the educational mortality gap in the remote rural area of Cuatro Santos to be smaller than in the rural area of León. Both regions share similarities in work activity, with agriculture and raising livestock being the main sources of income. Moreover, rural León has more access to health services, while in Cuatro Santos severe cases need to be transported by ambulance to the nearest hospital 130 km away. This child mortality pattern has been found in other places. For example, one study in Brazil found that child mortality in remote areas was the lowest (123). Furthermore, evidence from Millennium Villages in Africa indicates that child mortality is lower in areas where community interventions have been established than in non-millennium villages (124). Such community actions may strengthen social cohesion among the villagers.

Social cohesion is the capacity of people to create an environment of trust among one another (125). One study in a poor area in Ethiopia found that increased social networking among women of reproductive age was associated with an improvement in child survival (126). Similarly, a study by Peña et al. (2000) in León found that infant mortality was lower among poor mothers residing in a poor neighborhood than among poor mothers with non-poor neighbors, perhaps the result of a strong social network when people share the same socio-economic position (110). A study in rural areas of Butajira found that people who did not participate in organizations had the highest risk of child mortality (127). Cuatro Santos is an area that has recent-

ly experienced positive socio-economic development: NGOs and the local government are involving people in projects, and this may be increasing the social cohesion of the population more than in other places such as the León municipality. These issues need to be explored further, especially in León, where data on participation in interventions has not been collected.

Urban–rural differences in mortality

The locations we have studied are all on track toward MDG4, and are likely to meet that goal by 2015. Mortality in the urban area of León was lower than in rural León and Cuatro Santos. This difference is consistent with evidence from other settings in LMIC (128). In urban areas, certain socio-economic indicators tend to be better than in rural areas, and access to health services is clearly more available. However, although urban León has health centres, a referral hospital, and private clinics according to the trends from 1997 to 2005, child mortality has increased. The same has occurred in other places, suggesting that urbanization may have a negative impact on child survival for populations that have settled (e.g., slums) where environmental conditions are not good for health (129).

Community interventions to achieve MDG1

Interventions that reduce poverty have been innovative and on the increase. If they are successful, the poor will become non-poor, something described in the literature as a poverty transition (130,131). We assessed the poverty in Cuatro Santos using the Unsatisfied Basic Need Index (UBNI). We found poverty to be high there, and greater than at the national level. However, the reduction reported was larger than at the national level. But poverty assessment reports have shown that despite poverty being higher in rural than urban areas, reduction has been achieved more rapidly in rural areas (132).

In rural areas, the reduction of poverty has focused on investment in agriculture and livestock. However, non-farm activities have been gaining ground in improving the rural economy. We assessed the association between a set of community developmental interventions and the transition of families from poor to non-poor status.

Safe water and sanitation

Providing safe drinking water and sanitation are both targets for MDG7. Progress toward this goal advances MDG1 and other MDG as well. Lack of these basic needs is linked to poor health (133). Child health is dependent on these essentials. Diseases related to the lack of safe drinking water and sanitation may increase financial costs (e.g., transport or medicine) that profoundly affect the low financial resources of rural families. Also, rural fami-

lies have traversed great distances to obtain safe drinking water, and children are often responsible for this task.

We found that the access to piped drinking water increased from 18% in 2004 to 28% in 2009. Similar figures are found at the national and international level from rural areas (17,103). A study conducted in Cuatro Santos found that water installations were inequitably distributed: households close to the main road had more benefit of that intervention because water installation depends on access to electrical power. Latrine interventions have increased in the area, reaching a proportion of 80%, higher than that reported on the national level; similar figures have been reported in the rural area of the León municipality.

Microcredit, home gardens, and technical education
Findings from Cuatro Santos revealed that microcredit, home gardens, and technical training were associated with poverty transition from poor to non-poor. This initiative began in Bangladesh with founding of the Grameen Bank as an alternative to incentivize investment among the poorest, help reduce, and increase growth in LMIC (134,135).

The impact of microcredit on different components of poverty has been found heterogeneous in LMIC. Some methodological aspects of studies that have been conducted prevent us from getting a clear picture of the role of microcredits. Randomized control trials are best able to evaluate the effect of interventions like microcredit, but this interventions design is less used in many contexts.

A systematic review of studies conducted in sub-Saharan Africa found a positive impact of microcredits on housing investment. Negative associations were found with regard child educational enrollment. In one country, school enrollment was higher for boys than girls among microcredits clients (136). Moreover, microcredit was found to have no impact on job creation. On the other hand, a review of studies in Latin America found more positive associations between microcredits and housing investment, business performance, education, and school enrollment (137). We found microcredit participation higher among the non-poor than it was for the poor and extremely poor population. This pattern has also been found in other settings in Latin America (138). High interest rates in applying for a loan might limit poor and extremely poor people from seeking microcredit.

Our findings indicate that participation in home gardening was associated with a poverty transition from poor to non-poor. The involvement in this activity was equal between poor or extremely poor and non-poor households. Home gardening is an agricultural intervention where a small plot of land is used for to cultivate crops (139). The gardens are generally close to the household and are more common in rural areas. The impact of home gardening varies according to the literature. Most reports are focused on nutritional

outcomes (e.g., consumption, diet, vitamin A, and child anthropometric indicators), and few consider the direct effect on poverty reduction.

Between the association of home gardening and nutritional outcomes, household income generation is a mediating factor. A systematic review performed in sub-Saharan settings found five studies where home gardening improved household income, however, only one showed significant differences (140). A broader review in several worldwide regions found seven out of nine studies where home gardening strengthened human capital with the use of nutritional education and gender considerations, especially because women were the principal managers of home gardens. Four out of these seven studies showed that home gardening improved household income (141). A study in Bangladesh also concluded that women involved in home gardening gain power for making decisions, raise family income, and contribute more to the household (i.e., education, clothing, and health). However, reviews find that most studies of this kind exhibit methodological problems that limit conclusions on the benefits of home gardens, as those studies generally do not reach statistical power.

Our study did not measure the income generated from home gardens. However, as stated earlier, depending on the size, type of crops, and seasons, a part of the produce may be sold to complement needs in the household. A study of Nicaraguan families with home gardens revealed that at least 60% of the family income came from the home gardens (142). The general population might also gain benefit from the fruits or vegetables available through home gardens, and home gardens may enhance their participation in other social programs such as safe water or sanitation.

Technical training or technical and vocational education programs provide skills for work; generally it is to those who have not completed secondary school, for whom it may accelerate their entry into the labor market (143). Traditionally, technical training was considered as a poor educational choice and with higher costs than the general education (i.e., secondary), but less expensive than a career at the university. In rural areas this type of education may encourage the disadvantage to continue their formal studies, but in a way that will generate income. However, access to technical training still is unequal in many countries. For example, in India access to technical training in rural areas is 3%, but in urban it is 6%. A similar situation was observed in sub-Saharan African countries such as Tanzania (144), where access to a non-farm related job is difficult, technical training might be seen as an investment (145). Thus, a study performed in Uganda found that young people are more likely to pursue a technical education when they have access to unconditional credit (146).

Technical education was found to be unequal between poor or extremely poor and non-poor people in 2004, but this gap disappeared by 2009. However, technical training was also associated with a reduction of poverty in

our panel of households. In Nicaragua, unemployment is higher in rural than in urban areas, but the proportion of people with a technical education is higher in rural (48%) than in urban (28%) areas (103). The returns from technical training may be through self-employment, migration to other places for a job with a better salary, or continuing to study at a higher level.

Spatial clustering has had many applications in public health surveillance (147). The identification of clusters for certain health conditions helps to prioritize interventions. We have used this technique to identify concentrations of poor households and community interventions. We found that high clusters of poverty overlapped with clusters with low coverage of total interventions. Participation in some individual interventions (e.g., microcredit, safe water, and latrines) was more likely to be found in high clusters of households of low poverty; by contrast, home gardening participation was found less in clusters of low poverty.

Methodological considerations

Papers 1 and 2: Child mortality
For this study, child mortality was measured using full birth histories (148,149). This method is used in settings without good registration systems but may be the subject of biases. One such is recall bias, which occurs when the respondent does not remember when either childbirth or death took place. Early deaths (e.g., neonatal) might be underreported due to this bias in mothers with low SEP. A local calendar with dates of special events aided during the data collection to narrow down the precise dates of mortality registered in the HDSS.

Maternal deaths, in-migration, and out-migration may also affect child mortality estimation, and its differentiation by SEP. Births histories were not obtained for mothers who had died. However, the magnitude of maternal mortality in Nicaragua and mainly in the region where the study was performed is less likely to bias our child mortality estimations. Background characteristics of mothers involved in internal migration may differ from the rest of the population in place of origin or destination. However, no data about migration status of mother was asked before the baseline. This issue should be explored more closely in future studies.

Education was measured at the moment of the interview in León and Cuatro Santos. A misclassification bias might have occurred for differences in mortality by maternal education for long periods of time before the date of the interview. Mothers may have improved their educational level from non-formal to formal, and this could consequently result in underestimating the mortality level of the non-formal educational group in the past. After the

baseline of the HDSS, this type of bias has been minimized in continually updating figures on maternal education.

The low rejection rate (< 0.1%) of participation during interviews reported in both settings enhances the ability to generalize our results to other areas. However, both settings are located in the Pacific region of Nicaragua and findings of this study cannot be generalized to areas such as the Central and Caribbean regions of the country, where life styles differ from those in our study. During the last year of the study period, the number of child deaths grew very small, and in the case of Cuatro Santos, it limited our power to find statistical significance in the analysis regarding social inequalities and child mortality.

Papers 3 and 4: Poverty, interventions, and other MDG
In the HDSS, no data for measuring the level of poverty based on the $1.25 subsistence amount was collected. Instead, the HDSS based its poverty assessment on unsatisfied basic needs, as previously used in the same areas of Nicaragua.

Data on participation in interventions was obtained only in Cuatro Santos. Information about who provided the intervention was not collected. Therefore, the participation might have been selective for certain population groups. NGOs and government agencies target populations differently, in accordance with their plans. In order to model the complex structure between interventions and poverty transition a propensity score approach was implemented. However, we are aware that residual confounding due to other unobserved variables may remain in this relationship.

Although the HDSS has a longitudinal nature by design, it was not intended to measure the numbers of children who began first grade and completed the last grade of primary school, one of the targets of MDG2. For example, children might not continue attending school because of a change in residence, and it cannot be considered as a dropout.

Conclusions

At the time of writing, three years remain to the end of the MDG. Since 2000, we have been witnessing how this global commitment has been playing out in various countries.

We found that the under-five mortality rate in our study settings in Nicaragua was reduced sufficiently to achieve MDG4. Narrowing social inequalities suggests accelerating progress. Even in the poorest areas, if children of low socio-economic position can benefit from life saving interventions, then achieving MDG4 is possible. Furthermore, efforts to reduce neonatal mortality rate are crucial. A major investment in the provision of healthcare is required to insure an equitable approach to good quality health services so that newborn lives might be saved. The solution exists, if there is a will to put it into place.

We identified a set of interventions associated with the transition from poor to non-poor. Although some of them were unequally distributed, it indicates that poor rural populations are motivated to participate in different community actions designed to strengthen social cohesion and combat the poverty. We found that access to safe water is a persistent challenge, particularly in remote rural areas. In certain areas where poverty was concentrated, participation in interventions designed to help overcome impoverishment was low.

This thesis reveals the necessity of monitoring aspects of human development in different social stratifications. Further, this work provides the Nicaraguan government, NGOs and stakeholders working on MDG in similar contexts with transferable and eminent lessons on which interventions have a great impact and how they are being scaled-up. There are undeniable limitations and challenges to be considered when analyzing data, or introducing interventions strategies. Data is an investment for the present and the future. It is hoped that the good will of a nation makes 2015 not only the end of MDG, but the beginning of a new plan— A plan where equity and sustainability become bases to reach the next generation of goals.

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