ADDIS ABABA UNIVERSITY
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Evaluating the Effects of Irrigation on Poverty and Inequality in Banja Woreda-Amhara Region

By

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DECLARATION

This Thesis is my own original work, has not been presented for a degree in any other university, and that all sources of material used for the thesis have been duly acknowledged.

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Abstract

This thesis is focused on evaluating the effects of irrigation development in Banja Woreda on poverty and income distribution. Using multivariate analysis, the determinants of rural income has been assessed. To avoid the problem of omitted variables that creates inconsistency in estimation, the fixed effects model has been employed. The researcher has also used Gini coefficients to evaluate the impact of irrigation on income distribution.

From the study, it was found that our key variable, irrigation, is a significant determinant of total income of rural households. Hence, using the simulation framework, irrigation has been witnessed to have a greater contribution in reducing poverty incidence in the study area. In addition to this, the signs and significance of coefficients of other important variables such as dependency ratio, household size and proportion of output affected by negative shocks were found as expected. Moreover, income of households that is attributable from irrigated lands was found influential in abating income inequality among rural households in the study area. Thus, continued investment in new irrigation projects and maintenance of existing systems in Banja Woreda will help to attain the government's rural welfare improvement goals. Moreover, as reducing poverty and decreasing inequality both have growth-enhancing effects; irrigation investment could have an added benefit. Therefore, Irrigation investment in rural Banja Woreda appears to be an investment that can lead to both growth and equity.

CHAPTER ONE

1. INTRODUCTION TO THE THESIS

1.0 Introduction

Though food security is a top economic development agenda for many least developed countries, only few have been successful with the help of the Green Revolution. Many countries, however, have failed to succeed. The Green Revolution was an agricultural technology introduced in the 1970s and 1980s that has brought remarkable improvements in the livelihoods many agrarian societies especially in the South-East Asian countries. This technology was mainly based on the use of improved seeds, chemical fertilizers and irrigation as pillars for agricultural development.

> 'Water is life'. This simple statement embodies the crucial role that water plays to individuals, families, communities, nations and regions. Without adequate water the human body cannot survive; when droughts occur societies could easily be destabilized and famines could become rampant. History is replete with civilizations that have risen on the banks of ancient rivers such as Tigris and Euphrates, the Nile, the Niger, the Zambezi and many more. Water has been providing nourishment, leads to an environment for healthy populations and is the basis of agriculture and industry. In modern times, sustainable socio-economic progress is seldom possible without adequate development of water resources to support food production, industry, the environment and other human needs.[1]

> In Africa, 407.4 million people out of a total population of 804 million are extremely poor, making poverty reduction the highest priority in Africa's development agenda. Poverty, being heterogeneous with dimensional links to problems of hunger, illiteracy, child and maternal mortality, and diseases is a fundamental challenge facing Africa as well as the rest of the world. That the problem of poverty is of global concern is underscored by the United Nations (UN) Millennium Development Goals (MDGs) on poverty which calls for a reduction (by half) of the 1.2 billion people currently living below a dollar a day by 2015.[2]

Table 1 below shows the breakdown of the poor as a percentage of the total population in the regions of the world.

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[1] Stephen M.K. Donkor, 2004
[2] Felicia O. Akinyemi; 2005

Table 1: Population below $1 purchasing power parity (PPP) per day

Percentage of population living below a $1 per day[a]			
Region	**1990**	**1999**	**2001**
Northern Africa	2.6	2.0	1.9
Sub-Saharan Africa	46.9	42.7	46.6
Latin America and the Caribbean	10.6	10.6	10.0
Eastern Asia	33.0	17.8	16.6
Southern Asia	39.7	30.5	30.4
South-Eastern Asia	18.4	10.8	10.2
Western Asia	1.6	4.2	3.7
Commonwealth of Independent States	0.5	10.3	5.0
Transition countries of South-eastern Europe	0.4	1.7	2.1

[a] High-income economies, as defined by the World Bank, are excluded (source: UN, 2004)

From the above table, it is possible to observe that Sub-Saharan Africa (SSA) has the highest percentage of population living below 1 US $ per day. Southern Asia has the next highest percentage of extremely poor people. However, in contrast to Africa, Southern Asia depicts a consistent decline in the percentage of population below $1 over the years. Northern Africa and Transition countries of South-Eastern Europe exhibit a very low percentage.

> Though Africa's share of global fresh water resources (10 percent) closely matches its share of world population at 12%, its distribution is uneven-ranging from areas of severe aridity like the Sahara and the Sahel in the north, and the Kalahari in the south, to the Congo Basin, which is estimated to have fifty per cent of Africa's fresh water. In addition to this, the continent suffers from one of the most unstable rainfall regimes in the world. (Stephen M.K. Donkor, 2004)

According to the report of IMF(1999) and Bigsten et al (2003), Ethiopia is rated as one of the poorest countries in the world with GDP per capita of around USD 100, while life expectancy, educational enrolment, and other indicators of well-being are all extremely low. Agriculture remains the dominant economic sector contributing about 45% of GDP.

Currently, Ethiopia is exerting much effort to bring about fast and sustainable development and has launched various programmes in order to do so. One such program is the construction of irrigation schemes all over the country especially in areas where irrigation water is available. Hence, the aim of this paper is to empirically investigate the impact of these irrigation projects in one of the selected woreda of the country.

1.1 STATEMENT OF THE PROBLEM

According to the report by FAO (2002a), although enough food is being produced to feed the world's population, there are still some 840 million undernourished people in the world, 799 million of whom live in developing countries. This situation led the World Food Summit in 1996 to set a goal of halving the number of hungry people by 2015. The recent FAO State of Food Insecurity in the World Report concludes that progress towards this goal has slowed to almost zero. The data indicate that the number of hungry people has decreased by 2.5 million/year since 1992. If this trend continues at the current pace, the World Summit's goal will be achieved more than 100 years late. To reach the goal by 2015, the annual decrease in the number of hungry people would have to rise tenfold to 24 million. As Jacques Diouf, the FAO Director General, wrote in the foreword to the 2002 State of Food Insecurity in the World Report, the cost of inaction is prohibitive; the cost of progress is both calculable and affordable.

> In Africa, agriculture forms the backbone of most of the continent's economies, providing about 60% of all employment. During the last decade, per capita agricultural production has not kept pace with population growth. Consequently, as per FAO's assessments, at the end of the 1990s, 30 countries in Africa had over 20% of their population undernourished, rising to 35% in the 18 worse affected countries. In terms of absolute numbers 200 million people were malnourished between 1997 and 1999, with 194 million of these people living in SSA. The food gap estimated at 17 million tons in 2000 was filled

by imports (14.2 million tons) and food aid (2.8 million tons) at a cost of US$18.7 billion. Close to 30 million people required food emergencies due to droughts, floods and civil strife in 2001.[3]

Food security is a fundamental objective of most underdeveloped countries especially those countries in Sub-Saharan Africa. From the Green Revolution, it was observed that countries like India, Philippines and Thailand were able to achieve food self-sufficiency within a short period of time. We know that irrigation water was the main component of the Green Revolution and hence to achieve this objective certainly irrigation is a key factor. Today many countries are focusing their attention on the development of irrigation.

Currently, in Ethiopia we observe an increasing concern to the development of irrigation in many parts of the country. This paper tries to investigate the link among irrigation, poverty and inequality in the existing irrigation practice in a selected *woreda* of Ethiopia.

1.2 OBJECTIVES OF THE STUDY

Ethiopia, a country with massive irrigation potential, couldn't utilize its resources well enough to bring about rapid agricultural development. A significant proportion of its population is forced to lead its life under poverty. Currently, Ethiopia is trying to bring about fast and sustainable development. One of these endeavors is the construction of large scale irrigation schemes in many parts of the country. But, can we say that such schemes (projects) are serving the planned poverty alleviation goal? Does irrigation bring about equity among the income of farmers? This research paper tries to address these and other related issues such as poverty, education and consumption status of rural households.

The overall goal of this paper is to examine the impact of irrigation on income, poverty and income distribution in Banja woreda of the Amhara region.

[3] FAO, 2002b

To meet the overall goal, the paper pursues three specific objectives.

1. Examine the relationship between irrigation and income using both descriptive statistics and multivariate analysis.
2. Explore the impact of irrigation on poverty incidence.
3. Uncover the effect of irrigation on income distribution.

1.3 HYPOTHESES OF THE STUDY

The thesis tries to test the following two hypotheses:

- In Northern Ethiopia, settled agriculture is a predominant activity for centuries. In this area of the country, income from agriculture is a major component of household income. Thus, any intervention that affects production would influence total income of households. Therefore, my first hypothesis is to explore the relationship between irrigation and income of households in the study area.
- The second hypothesis is to investigate the effect of irrigation on poverty and income distribution of rural households in Banja Woreda-Amhara Region.

1.4 SIGNIFICANCE OF THE STUDY

In countries like Ethiopia, where drought is a frequent phenomenon, developing irrigation can play a significant role in achieving one of the nations' top priorities, i.e., food security. In line with this view, this study will have an important contribution in indicating the impact of irrigation on poverty and inequality. In addition to this, this study can evaluate whether the existing irrigation schemes in the study area are serving the planned poverty alleviation goal or not. Moreover, the paper will provide information to both federal and regional level policy makers that could help decision making processes in developing irrigation projects. More importantly, this study may enable those who are interested in this matter to briefly see the role that irrigation plays for poor households in the study woreda.

1.5 SCOPE OF THE STUDY

The analysis of this paper involves assessment of the impact of irrigation on poverty and inequality limited only to Banja Woreda of the Amhara Region. Banja woreda is one of the Nine Woredas in Awi Zone. Kosober is the capital town of the Woreda as well as that of Awi Zone. Large scale irrigation has been practiced in the area for more than 25 years. The scope of this paper is limited to analyzing small-scale irrigation on household level and not at the national level.

1.6 DATA SOURCES AND METHODOLOGY

The sources employed to prepare this paper is mainly based on primary sources through interviewing households, concerned officials and professionals on the area. Attempts were made to use of reference books, journals, proceedings and websites with the relevant literature on the issues to be investigated in this study.

Methodology

In this thesis, I have used three models [based on the model developed by Q. Huang et.al (2005)] of linking irrigation to income of households, poverty and income distribution. A detailed description of the model is found in chapter three of the thesis. However, I have written a brief illustration of the model hereunder.

Model 1: Linking Irrigation to Income of Households

In this part, the determinants of income can be analyzed by making income a function of a set of household and village level characteristics, including household irrigated area. It uses a multivariate analysis to find the determinants of income. However, in this approach, it is possible that there can be a problem of omitted village variables in the model that may create inconsistency in our estimation. Hence it is advisable to use a village dummy to capture all village fixed effects that may affect our analysis. In this case, we select the fixed effects model to control the problem of excluding unobserved village characteristics in the model.

Model 2: Linking Irrigation to Poverty

To study more carefully the effects of irrigation on poverty, we use a simulation approach in order to assess the change in poverty incidence arising from a change in a specific factor. To do so, we follow Datt (1998) and Gibson and Rozelle (2003) cited in Q. Huang et al (2005) and use parameters from a regression analysis of the determinants of total income to create a simulation framework. More specifically, the basic model is of (log) income per capita, *yhv*, deflated by the poverty line, *c*, a ratio known as the "welfare ratio".

In this model, a weighted average of the household probabilities of being poor gives the predicted incidence of poverty, where the weights are the household sampling weights in terms of household size.

Using a simulation framework, it is possible to look at the effects of increasing irrigated land on poverty reduction. That is, the incidence of poverty may fall/rise by certain percentage points if all non-irrigated land were converted to irrigated land. Thus, the simulation work will clearly show us the effect of irrigation on poverty reduction.

Model 3: Linking Irrigation to Income Inequality

To analyze the impact of irrigation on inequality, I have chosen two ways of decomposing inequality:

1. Decomposition by *source of income* (cropping income from irrigated plots, cropping income from non-irrigated plots, off farm income and other income); and
2. Decomposition by estimated *income flows due to specific household characteristics* (e.g.,

irrigated land area per capita and literacy of household’s head).

Our methodology is similar in both cases. We decompose the Gini coefficient for total household income as a weighted sum of the inequality levels of incomes from different components, with the weights being functions of the importance of each component and the correlation of each component with total income.

1.7 LIMITATION OF THE STUDY

This paper is mainly based on primary sources. As it is evident from the topic, the paper has focused on the effect of irrigation on poverty and income inequality among rural households in the study area. It does not, however, try to investigate other determinants affecting poverty and income distribution. Hence, the result of this study wouldn't give a conclusive evidence of all factors that may impact on poverty and income distribution of rural households in the study area. Moreover, the research may not show the income status of farmers exactly since households do not have a record on their expenditures and revenues. The data has been collected for a sample of 150 households taken from one selected woreda (Banja) in the Amhara Region. Hence, the policy recommendation of this paper is applicable only to the study area. If it were not for financial, material and time constraints, its finding would be more relevant had the study be done at national level.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 THEORETICAL LITERATURE

2.1.1 DEFINITIONS AND CONCEPTS OF POVERTY

There is no one single definition of poverty. Here are some of the definitions that different organizations use when they're talking about poverty.

> **Poverty** is the state of being without the necessities of daily living, often associated with need, hardship and lack of resources across a wide range of circumstances. For some, poverty is a subjective and comparative term; for others, it is moral and evaluative; and for others, scientifically established. [4]
>
> "Poverty is defined relative to the standards of living in a society at a specific time. People live in poverty when they are denied an income sufficient for their material needs and when these circumstances exclude them from taking part in activities which are an accepted part of daily life in that society."
>
> **Scottish Poverty Information Unit**
>
> "The most commonly used way to measure poverty is based on incomes. A person is considered poor if his or her income level falls below some minimum level necessary to meet basic needs. This minimum level is usually called the "poverty line". What is necessary to satisfy basic needs varies across time and societies. Therefore, poverty lines vary in time and place, and each country uses lines which are appropriate to its level of development, societal norms and values."
>
> **The World Bank Organization**
>
> "There are basically three current definitions of poverty in common usage: absolute poverty, relative poverty and social exclusion. Absolute poverty is defined as the lack of sufficient resources with which to keep body and soul together. Relative poverty defines income or resources in relation to the average. It is concerned with the absence of the material needs to participate fully in accepted daily life. Social exclusion is a new term used by the Government. The Prime Minister described social exclusion as "…a shorthand label for what can happen when individuals or areas suffer from a combination of linked problems such as unemployment, poor skills, low incomes, poor housing, high crime environments, bad health and family breakdown."
>
> **The House of Commons Scottish Affairs Committee**

[4] *Wikipedia-free encyclopedia*

Definitions of **poverty** on the Web:

- the state of having little or no money and few or no material possessions
  wordnet.princeton.edu/perl/webwn
- Poverty is the state of being without, often associated with need, hardship and lack of resources across a wide range of circumstances. For some, poverty is a subjective and comparative term; for others, it is moral and evaluative; and for others, scientifically established. The principal uses of the term include: Descriptions of material need, including deprivation of essential goods and services, multiple deprivation, and patterns of deprivation over time. ...
  en.wikipedia.org/wiki/Poverty
- Following the Office of Management and Budget's (OMB's) Directive 14, the Census Bureau uses a set of money income thresholds that vary by family size and composition to detect who is poor. If the total income for a family or unrelated individual falls below the relevant poverty threshold, then the family or unrelated individual is classified as being "below the poverty level." Related term: Income.
  atlas.library.arizona.edu/glossaryk_p.htm
- A state in which a family's income is too low to be able to buy the quantities of food, shelter and clothing that are deemed necessary.
  www.econ100.com/eu5e/open/glossary.html
- A person is "poor" or "in poverty" if they reside in a household with income below the US poverty threshold, as defined by the US Office of Management and Budget. Poverty thresholds differ by family size and are updated annually for inflation using the Consumer Price Index. However, they do not take into account geographic differences in the cost of living.
  irhr.ua.edu/blackbelt/glossary.html
- State of being deprived of the essentials of well-being such as adequate housing , food, sufficient income, employment, access to required social services and social status.
  www.undp.org/rbec/nhdr/1996/georgia/glossary.htm
- The condition of being poor or deprived of material belongings.
  216.168.47.67/cis-fishnet/Crest/CRD.htm
- State of being poor; lack of income for providing material needs.
  www.futureharvest.org/about/glossary.shtml
- A situation in which a person or household lacks the resources necessary to be able to consume a certain minimum basket of goods. The basket consists either of food, clothing, housing and other essentials (moderate poverty) or of food alone (extreme poverty).
  www.agtrade.org/glossary_search.cfm
- the state of one who lacks a usual or socially acceptable amount of money or material possessions
  www.education.eku.edu/Faculty_Staff/resorc/TheOrphanTrain_KParrett.htm
- This is where people are poor, have no savings, own very little and often have low living standards.
  geographyfieldwork.com/GeographyVocabulary7.htm
- The condition of possessing an income insufficient to maintain a minimal standard of living. Definitions of poverty are culturally specific, and thus relative to the social norms and expectations endemic to a given nation-state. However, the condition of absolute poverty (ie lacking the income to maintain a minimum diet) is acknowledged worldwide.
  media.pearsoncmg.com/intl/ema/uk/0131217666/student/0131217666_glo.html

Poverty is also defined by www.britannica.com as

> The state of one whom lacks a usual or socially acceptable amount of money or material possessions. Poverty is said to exist when people lack the means to satisfy their basic needs. In this context, the identification of poor people first requires a determination of what constitutes basic needs. These may be defined as narrowly as "those necessary for survival" or as broadly as "those reflecting the prevailing standard of living in the community." The first criterion would cover only those people near the borderline of starvation or death from exposure; the second would extend to people whose nutrition, housing, and clothing, though adequate to preserve life, do not measure up to those of the population as a whole.[5]

The problem of definition is further complicated by the non-economic connotations that the word poverty has acquired. Poverty has been associated, for example, with poor health, low levels of education or skills, an inability or an unwillingness to work, high rates of disruptive or disorderly behavior, and improvidence. While these attributes have often been found to exist with poverty, their inclusion in a definition of poverty would tend to obscure the relation between them and the inability to provide for one's basic needs. Whatever definition one uses, it is understandable that the effects of poverty are harmful to both individuals and society.

> Although poverty is a phenomenon as old as human history, its significance changed in the 20th century. Under traditional (i.e., non-industrialized) modes of economic production, widespread poverty had been accepted as inevitable. The total output of goods and services, even if equally distributed, would still have been insufficient to give the entire population a comfortable standard of living by prevailing standards. In the 20th century, however, this ceased to be the case in the highly industrialized countries, whose national outputs were sufficient to raise the entire population to a comfortable level if the necessary redistribution could be arranged without adversely affecting output. Among such countries were virtually all those of western Europe and some in central Europe, the United States and Canada, Japan and several smaller nations on the Pacific rim, the oil-rich nations of the Arabian Peninsula, and Australia and New Zealand. Poverty in these countries tended to have different patterns of distribution than in much of the rest of the world.[6]

We could identify several types of poverty based on such factors as time or duration (long- or short-term or cyclical) and distribution (widespread, concentrated, and individual).

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[5] *http://www.britannica.com cited in United States Census Bureau,*

http://www.census.gov/hhes/poverty/poverty00/pov00hi.html

[6] *http://www.britannica.com cited in United States Census Bureau,*

http://www.census.gov/hhes/poverty/poverty00/pov00hi.html

There is sufficient consensus about the meaning of the term "poverty" that much is written without precisely specifying how the term is being used. However, when we turn to empirical studies and compare the alternative ways poverty has been measured, some people who are classified as poor by one measure are not so classified by another. If we could demonstrate that these alternative measures were basically equivalent, then we would be free to compare findings between studies using different measures. If, on the other hand, we found evidence of marked differences among alternative measures, careful consideration would have to be given to the way poverty is measured when contrasting the results of different studies. Such a finding would also raise questions about which categories of the population are most severely afflicted poverty; this in turn might well have major implications for the allocation of anti-poverty resources.[7]

2.1.2 STATE OF POVERTY AND INCOME INEQUALITIES IN THE WORLD

Until the recent past, the analysis of economic inequality in a country was essential a macro level exercise. Currently, it has been well recognized that macro level inequality measure is inadequate for assessing a country's economic development and distributional pattern. To have a clear understanding of the nature, structure and factors responsible for inequality decompositions of aggregate inequality in to sectors, sources and determinants of income are essential. The concept of decomposition of inequality signifies that if the population of income recipients is partitioned in to a number of sub-populations, the total inequality of the population can be expressed as sum of the inequality within the sub-populations and of the inequality between them.[8]

During the last couple of years, development economists emphasized the need to analyze the contribution of various components towards the total inequality in lieu of measuring the inequality at macro level only. Many empirical works on decomposition have been carried out by a number of authors in the less developed countries of Asia. Noted among them are Meharan(1974) for Iranian cities, Mangahas (1975) for areas and regions of Phillipines, Pyatt(1976) for urban and rural areas in Sri Lanka. Important contributions on measurement and decomposition of inequality may also be seen in Sen (1978), Atikinson(1978), Szal and Robinson(1977), Champernowne(1974) e.t.c. This type of investigation has importance in explaining the cause of higher inequality, measuring inequality within the sub-populations and determining the amount of inequality accounted for between the sub-populations.[9]

Economic inequalities come in different forms which could be seen in various degrees in the society. There are, of course, some inequalities in the broader subject matter of economic inequalities which do not raise serious social problems. Thus it would be important for economic research to focus on inequalities, especially on their determinants, extent and direction.

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[7] Watts, 1967

[8] *Motiur Rahman and S. Huda, 1992 pp-83*
[9] *Motiur Rahman and S. Huda, 1992 pp-83*

Facts on Poverty and Inequality

According to Jeff Gates (1999) cited in World Bank (2003), we have the following facts on poverty and inequality in the world.

- The United Nations Development Program (UNDP) reported in 1998 that the world's 225 richest people now have a combined wealth of $1 trillion. That's equal to the combined annual income of the world's 2.5 billion poorest people.
- The wealth of the three most well-to-do individuals now exceeds the combined GDP of the 48 least developed countries.
- While global GNP grew 40 percent between 1970 and 1985 (suggesting widening prosperity); the number of poor grew by 17 percent.
- Although 200 million people saw their incomes fall between 1965 and 1980, more than 1 billion people experienced a drop from 1980 to 1993.
- In sub-Saharan Africa, twenty nations remain below their per capita incomes of two decades ago while among Latin American and Caribbean countries, eighteen are below their per capita incomes of ten years ago.
- UNDP reported in 1996 that 100 countries were worse off than 15 years ago.
- Three decades ago, the people in well-to-do countries were 30 times better off than those in countries where the poorest 20 percent of the world's people live. By 1998, this gap had widened to 82 times (up from 61 times since 1996).
- In 1998, that 20 percent of the world's people living in the highest-income countries accounted for 86 percent of total private consumption expenditures while the poorest 20 percent accounted for only 1.3 percent. That's down from 2.3 percent three decades ago.
- At present, 3 billion people live on less than $2 per day while 1.3 billion get by on less than $1 per day. Seventy percent of those living on less than $1 per day are women. With

global population expanding 80 million per year, World Bank President James D. Wolfensohn cautions that, unless we address "the challenge of inclusion," 30 years hence we will have 5 billion people living on less than $2 per day.

- Two billion people worldwide now suffer from anemia, including 55 million in industrial countries. Given current trends in population growth and prosperity-hoarding, three decades from now we could have a world in which 3.7 billion people are anemic.
- These related phenomena led UN development experts to observe that the world is heading toward "grotesque inequalities," concluding: "Development that perpetuates today's inequalities is neither sustainable nor worth sustaining."
- UNDP calculates that an annual 4 percent levy on the world's 225 most well-to-do people (average 1998 wealth: $4.5 billion) would suffice to provide the following essentials for all those in developing countries: adequate food, safe water and sanitation, basic education, basic health care and reproductive health care. At present, 160 of those individuals live in OECD countries; 60 reside in the United States.

2.1.3 A BRIEF REVIEW OF POVERTY LINE

Poverty lines in Theory: A poverty line can be defined as the monetary cost to a given person, at a given place and time, of a reference level of welfare. People who do not attain that level of welfare are cosidered poor; and those who do are not. A distinction is sometimes made between “absolute poverty line” and “relative poverty line”, whereby the former has fixed “real value” over time and space, while a relative poverty line rises with average expenditure. Arguably, for the purposes of informing anti-poverty policies, a poverty line should always be absolute in the space of welfare. Such a poverty line guarantees that the poverty comparisons made are consistent in the sense that two individuals with the same level of welfare are treated the same way.

Objective Poverty Lines: As pointed out in Sen (1978), objective poverty line approaches can be interpreted as attempts to anchor the reference utility level to attain basic capabilities, of which the most commonly identified relate to the adequacy of consumption for living a healthy and active life, including participating fully in the society. Two methods of measuring objective poverty line are food energy intake and cost of basic needs.

The food-energy intake method: A popular practical method of setting poverty lines involves finding the consumption expenditure or income level at which food energy intake is just sufficient to meet pre-determined food energy requirements. Setting food energy requirements can be a difficult step. For instance, requirements vary across individuals and over time for a given individual. Food energy intake will naturally vary at a given expenditure level, y. Recognizing this fact, the method typically calculates an expected value of intake. Let k denote food-energy intake, which is a random variable.

The requirement level is k which is taken to be fixed (this can be readily relaxed). As long as the expected value of food-energy intake conditional on total consumption expenditure, *E (k/y),* is strictly increasing in y over an interval which includes k then there will exist a poverty line z such that

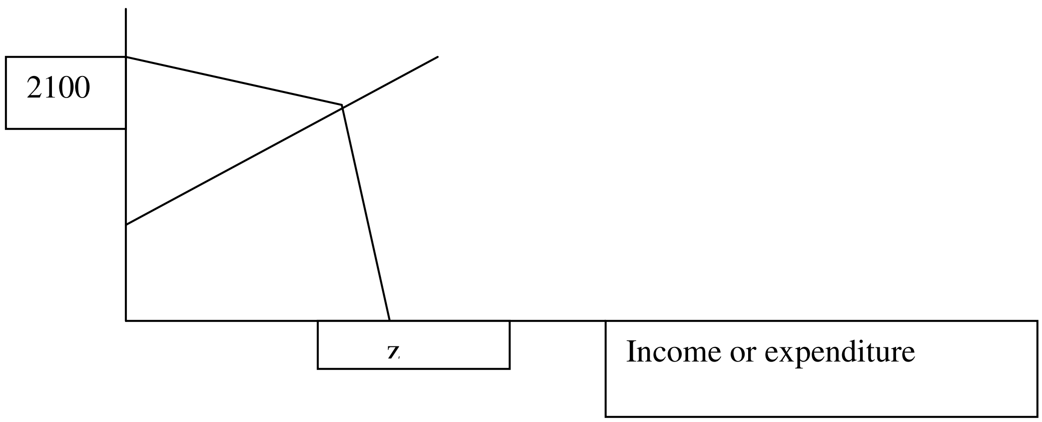
$$E(k/z) = k$$

This can be termed the "food-energy-intake" (FEI) method. As indicated in Ravallion M. and Bidani B. (1994), the method has been used in numerous countries; for example see Dandekar and Rath (1971), Osmani (1982), Greer and Thorbecke (1986), and Paul (1989).

Figure 2 illustrates the method. The vertical axis is food-energy intake, plotted against total income or expenditure on the horizontal axis. A line of "best fit" is indicated; this is the expected value of caloric intake at a given value of total consumption. By simply inverting this line, one then finds the expenditure z at which a person typically attains the stipulated food-energy requirement.

Figure 2: The Food-Energy Intake Method.

Food-energy intake
(Calories per day)



Once food-energy requirements are set, the FEI method is computationally simple. A common practice is to calculate the mean income or expenditure of a sub sample of households whose estimated caloric intake are approximately equal to the stipulated requirements. More sophisticated versions of the method use regressions of the empirical relationship between food energy intake and consumption expenditure. These can be readily used (numerically or explicitly) to calculate the FEI poverty line.

The cost-of-basic-needs method: This method stipulates a consumption bundle adequate for basic consumption needs, and then estimates its cost for each of the subgroups being compared in the poverty profile; this is the approach of Rowntree in his seminal study of poverty in York in 1899 [cited in Ravallion M. and Bidani B. (1994)], and since then it has been followed in numerous studies for both developed and developing countries. This is called the "cost-of-basic needs" (CBN) method. One can interpret this method in two quite distinct ways. It can be interpreted as the “cost-of-utility”, By the second interpretation, the definition of “basic needs” is deemed to be a socially determined normative minimum for avoiding poverty, and the cost-of-basic- needs is then closely analogous to the idea of statutory minimum wage rate. Poverty is then measured by comparing actual expenditures to the CBN. There are food and non-food components of CBN with different computation.

The Food Component: The food component of the poverty line is almost universally attached with nutritional requirements for good health. To compute the food component of CBN a simple method is to set a bundle of goods, say, in each region. One difficulty with the core basic needs method is the determination of the minimum requirement for the non- food needs. There are no agreed standards of needs for non-food items. This is because these non-food needs are determined by environmental conditions, as well as institutional structures, technology and customary modes of life. In order compute nonfood items the monetary value can be attached to most of the non- food items. But in using this method, it is necessary that the costs of the non-food needs included should not be lower than the prevailing cost for such items, even when the minimum standards are not met.

Subjective Poverty Lines: Subjective poverty line debate has opened another issue on poverty conceptualization and measurement. Psychologists, sociologists and others have argued that the circumstances of the individual relative to others in some reference group influence perceptions of well-being at any given level of individual command over commodities. As Scitovsky (1978) cited in Kapteyn et al (1988), “the dividing line… between necessities and luxuries turns out to be not objective and immutable, but socially determined and ever changing”. On the other hand as noted in Kapteyn et al (1988), some have taken this view so far as to abandon any attempt to rigorously qualify “poverty”. Poverty analysis has therefore, become polarized between the “objective-quantitative” schools and “subjective-qualitative” schools, with rather little effort at cross-fertilization. “Subjective poverty lines” have been based on answers to the “minimum income question” (MIQ), such as the following: “What income level do you personally consider to be absolutely minimal? That is to say that with less you could not make ends meet”. One might define as poor everyone whose actual income is less than the amount they give as an answer to this question.

Why Do We Have Poverty Lines?

According to David Ross et al (1994), poverty lines are needed for several reasons:

- Society needs a statistical indicator that tracks national and provincial estimates of the number and composition of households with low incomes. This indicator is essential for determining the size of the poor population and its composition– how many are lone-parent mothers, children, Aboriginal peoples and persons with disabilities? The measurement of a societal condition is a fundamental prerequisite to taking corrective policy action. Moreover, it seems that in modern societies, unless a societal condition has some statistical visibility it is deemed not to exist.
- International comparisons are needed to see how a country measures up against other countries.
- Measuring the impact on poverty of policy initiatives – such as Old Age Security, Employment Insurance, or the National Child Benefit, or of major cutbacks in government spending – is important.
- Frequently, local governments, school boards and community organizations need an income guideline to assist them in establishing eligibility for income targeted services such as transportation and housing assistance, school lunches, pre-natal care, and subsidized child care.

2.1.4 IRRIGATION AND AGRICULTURE

2.1.4.1 History of Agriculture & Irrigation

Farming dates all the way back to one of the first recorded civilizations, Mesopotamia (currently located in Iraq). Before 8000 B.C., the prehistoric people hunted and gathered. The Sumerians of Mesopotamia were the first to invent irrigation. Their society settled at the base of the delta, formed by the Tigris and Euphrates rivers. When the delta flooded the silt from the river bottom covered the land, mixing with soil and making it fertile. Unfortunately flooding was not only helpful, it was a threat to the Sumerian homes. After it flooded and the water had evaporated the ground was left caked in salt, rendering it almost impossible to reuse. This forced the Sumerians to find other methods of irrigation. They started to build canals to direct the water to different areas. This also allowed them to distribute the water in more precise amounts.[10]

Three thousand years ago during the height of the Persian Empire, one of the most crucial events that contributed to the development of irrigation happened. The Kareze irrigation system (also known as a Qanat) was formed. Engineers would build stone channels around streams to direct the water into town. Later they used aqueducts, which are a system of underground piping, to carry water to more precise locations in North Western Iran. The Persians built this system by first sinking a well to the level of the water table. Then they calculated where the point of a gently sloping tunnel would reach the surface. Finally they dug a tunnel to the well. They thought that if the Kareze system could be completed, they would gain power, and that other countries would pay to use their system. The success of this system intially helped the Persian Empire to rise but the construction of this elaborate system eventually began to use up too much time and money, causing the Empire to fall.[11]

In the 1700's agriculture took a huge leap called the Agricultural Revolution. The English landowners began experimenting with their methods, and enclosing their land. Jethro Tull invented the Seed Drill in 1701 because he thought that the usual way of planting seeds was wasteful. The Seed Drill allowed farmers to sow seeds in rows and at specific depths. Crop rotation was also a product of the Agricultural Revolution. Crop rotation is the process of alternating crops yearly on the same piece of land, in order to restore the nutrients that have been used up. All of these events contributed to what is now called the Agricultural Revolution. Many of these methods are still used today.

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[10] *Agriculture and Irrigation Today from www.bsi.vt.edu/ welbaum/pictures/ irrigation.html*
[11] *Agriculture and Irrigation Today from www.bsi.vt.edu/ welbaum/pictures/ irrigation.html*

Agriculture and irrigation have affected the rise and fall of many great civilizations. Without agriculture, our way of living would cease to exist as it does today. Without irrigation, we would not have agriculture.

> ~*Agriculture* is the farming of crops. It provides most of the world's food supply and helps support the economy.
>
> ~*Irrigation* is the act of moving water from one place to another and is used in farming to water crops.
>
> Without agriculture and irrigation the United States, as well as many other current civilizations, would not be as developed or as stable as they are today. The United States' economy is greatly affected and often determined by agricultural production. Though the US grows more agricultural produce than it needs, the nation is still affected when crop yields are low. The lack of water conservation in the United States is threatening crop yields as well as the environment, and our society. If we can't find a way to better conserve water, our civilization will be in danger of falling, just as Persia, Mesopotamia and others have in the past.[12]

2.1.4.2 The Role of Water in Agricultural Development

Agriculture has, arguably, been very successful at capturing the major share of the world's exploitable water resources. However, the environmental and socio-economic rationale for this capture by the sector is now being questioned. A new and more suitable approach to water resources allocation is necessary if the world's population is to be adequately fed, without further degradation and destruction of the planet's critical ecosystem services. Water productivity needs to be enhanced considerably, and economic cost-benefit analysis and pricing regimes can play a significant role in such a process. However, these economic measures will not be sufficient on their own. They will need to be reinforced by technological innovation and institutional changes

[12] *Agriculture and irrigation: The Sources of Life, Bryan Tunder, Gerlando Carmona and Kelly Gualco cited in ROCK Water Project Home Page*

in order to encourage a more equitable distribution of resources and to mitigate potential international conflicts across 'shared' water basins.

A. The Dominance of Agricultural Water Use

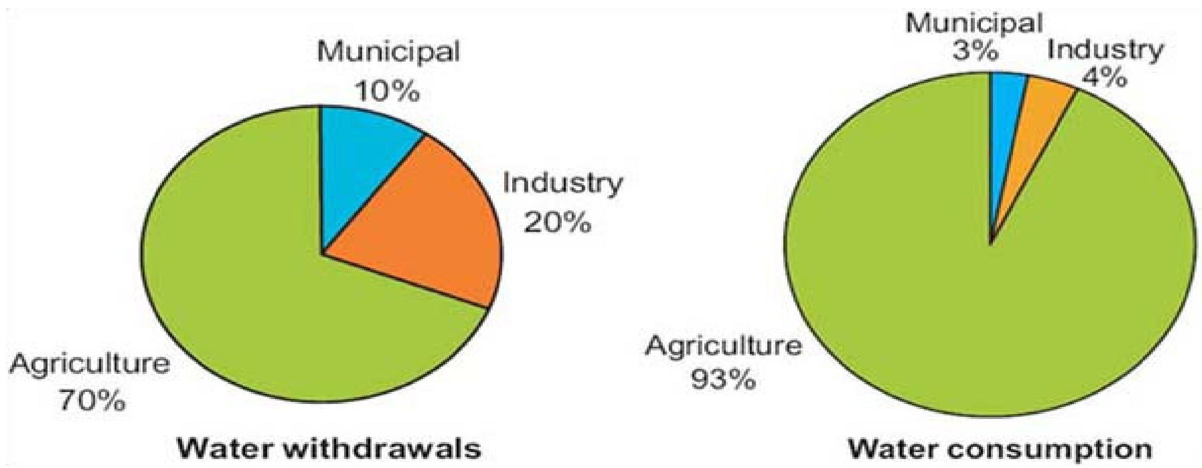
Irrigation is a vital component of agricultural production in many developing countries. According to FAO (2002a), in 1997-99, irrigated land provided two-fifths of crop production in developing countries, and accounted for about one-fifth of the cultivated area. The divergence in these statistics reflects the high crop yields and multiple cropping that are achieved through irrigation. Besides, Bruinsma (2003) found that developing countries are particularly dependent on irrigation: in 1997-99, 59 percent of cereal production in developing countries was irrigated. Food production in developing countries is increasing in response to the demands of an expanding population and rising prosperity. Some of this demand will be met by increased productivity of rain fed agriculture, some by increased imports, but irrigated agriculture will be a major contributor.

- According to FAO (2002a), agriculture is the largest user of water in all regions of the world except Europe and North America. In 2000, agriculture accounted for 70 percent of water withdrawals and 93 percent of water consumption worldwide, where consumption refers to withdrawals net of returns flows and evaporation (Figure 1 below). This is in contrast to industry, which accounted for 20 percent of withdrawals and 4 percent of consumption worldwide in 2000, and household use, which accounted for 10 percent of withdrawals and 3 percent of consumption. The water requirements of agriculture are large relative to water requirements for other human needs. The human body needs about 3 litres of water per day;

- For domestic uses people use approximately 30 - 300 litres of water per person per day;
- To grow their daily food needs people require 3000 litres of water per person per day.[13]

FIGURE-1

Water withdrawals and consumption



However, the agriculture sector is often criticized for high wastage and inefficient use of water at the point of consumption (i.e. at farm level) encouraged by subsidized low charges for water use or low energy tariffs for pumping.

> It is often claimed that the charges made for irrigation water, fail to signal the scarcity of the resource to farmers. This situation may persist because of entrenched interests, political problems associated with price reform, practical difficulties in measuring and monitoring water use, and social norms, e.g. perception of water as a free good and access to water as a basic right. These low charges can have an adverse impact on the effectiveness of irrigation systems and water use. They result in poor maintenance and consequent inefficient operation of existing irrigation systems, limited capacity for improvements or investment in new infrastructure, and waste of water at the farm level. Furthermore it is claimed that the subsidies provided for irrigation water tend to favour

[13] *FAO 2003a*

> the wealthy and thereby exacerbate inequalities in resource access and wealth distribution in rural areas.[14]

Water used for irrigation comes from surface water or groundwater. The use of groundwater for irrigation enables the extension of irrigated area beyond that which surface water alone can support. In addition, it assists with drainage of the soil (by lowering the groundwater table and providing drainage of soil water into tube wells). Groundwater can supplement surface water during periods of low flow, making surface water available for alternative uses. It is also used as a sole source of irrigation water. As pointed out in the works of Roy and Shah (2003) cited in FAO (2004), in India, more than half of irrigated land is supplied with groundwater, providing one-third of the country's food production. Groundwater has various advantages over surface water: it can be stored in aquifers for years with little or no evaporative loss; the percolation of aquifer recharge water through the ground attenuates pollution levels (making groundwater particularly suitable as a source of drinking-water, especially in areas with no water treatment facilities); groundwater can be withdrawn near the point of use; and it is available immediately on demand, which enables more timely applications of irrigation water.

> Surface water for irrigation is stored either in natural storage capacity (lakes and wetlands) or artificial capacity created through the construction of dams. Dams are usually constructed for the purposes of water storage for irrigation, hydroelectric power generation, flood control, or any combination of these. However, in the case of dual-purpose dams designed to store water for irrigation and hydroelectric power generation, conflicts can arise because increases in demand for irrigation water in the dry season exceed demand for power. This creates difficulties in the specification of the required storage capacity and the timing of water releases. The situation is yet more complex for dams also designed to provide flood protection. Effective provision of flood control requires storage capacity that is empty, but effective storage of water for hydroelectric power generation and irrigation requires storage capacity that is kept as full as possible (though seasonal flooding and flood prediction can limit these conflicts). Despite potential for conflict, provision of storage capacity for irrigation combined with other uses can have advantages. The combined value of storage capacity for multiple purposes may be required in order to make large dam developments economically viable. Moreover, the provision of storage capacity for non-agricultural uses can provide contingency against

[14] *De Moor and Calamai, 1997*

failure of irrigation schemes to meet predicted uptake and economic returns, e.g. through potential to develop further power generating capacity.[15]

The design and implementation of irrigation projects has traditionally been the domain of engineers and agronomists. Nowadays, in response to a commitment to a more developed approach to water management, a broader multidisciplinary perspective on irrigation is evolving. This approach incorporates social, cultural, environmental and wider economic impacts of irrigation projects. However, implementation of this perspective on the ground in the development and management of irrigation projects and programmes remains a persistent challenge. However, this challenge can begin to be addressed by the appropriate use of the functional approach to water management advocated above.

B. Irrigation and Agricultural Development Objectives

Governments and donors have traditionally justified allocation of water to agriculture on grounds of food security and rural development. These objectives are pronounced in developing countries where development is at low level and frequent food insecurity is common. Below, we will try to revise the various literatures written on two objectives of water allocation to agriculture namely food security and rural development.

Food Security

Irrigation enables greater agricultural production than is achieved with rain fed agriculture. The additional food production obtained with irrigation is essential for food security on a global level, and on a national level for some countries. National food security is attained either through the pursuit of self-sufficiency in food (i.e. meeting demand through domestic production) or through

[15] *FAO, 2004*

a combination of domestic production and imports. Food self-sufficiency was once a widespread objective and some nations still aspire to it. It creates savings in foreign exchange, protects domestic producers and consumers from the fluctuations of world markets, ensures rural food supplies and contributes to a political sense of national security.

> However, it has disadvantages. In arid countries, a self-sufficiency policy can increase allocations of water to agriculture at the expense of industrial and household water use, and can contribute to the over extraction of groundwater resources. Moreover, food supplies are vulnerable to extreme weather events, and shortfalls in supply then have to be met through imports, which eat into limited resources of foreign exchange. In response to various factors, which include increased water scarcity, reduced availability of agricultural land, and industrial growth, many countries have moved towards an objective of food security partly enabled by imports.[16]
>
> Global demand for food is increasing as the population continues to grow and increase in prosperity. Demand pressure is concentrated in developing countries, where demand for agricultural products is forecasted to increase at an average rate of 2 percent per year from 1999 to 2030. Food demand is also affected by a shift in diets, which is occurring in developing countries as a result of increased prosperity, urbanization and changing preferences. Populations in developing countries are tending to consume more livestock products, more fruit and vegetables, and fewer cereals than in the past. Meat consumption in developing countries is projected to increase by 44 percent per capita from 1997/99 to 2030.[17] Combined with a general shift in animal production from extensive (i.e. grazing) to intensive (i.e. cereal-fed) systems and the low efficiency of meat production, this is creating increased demand for cereals (such as maize) for animal feed. Cereals for animal feed account for half of the projected 70-percent increase in demand for cereals forecast to occur in developing countries between 1997/99 and 2030. Irrigation is used particularly important to produce cereals. For example, almost 60 percent of the cereal production in developing countries in 1997/99 comes from irrigated land.[18]
>
> Increased demand for food in developing countries will be offset at a national level, to various extents, by increased agricultural production. A 61-percent increase in annual cereal production is expected to occur in the period 1997/99-2030. With the exceptions of sub-Saharan Africa and Latin America (where rain fed agriculture has greater significance), irrigated agriculture will provide much of this increase. In developing countries collectively, irrigated agriculture will provide 57 percent of the additional 256 million tones of cereals that will be produced in 2025 relative to 1995. Irrigation increases agricultural production through both the expansion of cultivable area beyond that possible under rain fed agriculture and higher crop yields. FAO in its 2002 publication of Agricultural drainage water management in arid and semi-arid areas, by K.K. Tanji & N.C. Kielen predicts that 70 percent of the increase in agricultural production that is forecast to occur in developing countries from 2000 to 2030 will come through increased yields, 20 percent through expansion of crop area and 10 percent through increased cropping intensity (multiple cropping and reduced fallow). Irrigation increases yields not

[16] *FAO, 2002a*
[17] *Bruinsma, 2003*
[18] *FAO, 2003c*

only through reduction or prevention of crop water stress, but also through complementary benefits of combined use of irrigation with high yielding varieties, fertilizers and pesticides ('green revolution' technology). Yields for cereals produced with irrigation exceeded rain fed yields by 115 percent in developing countries collectively and by 150 percent in sub-Saharan Africa and West Asia/North Africa in 1995. Although yields for irrigated cereal production in developing countries are increasing by 1.2 percent per year, it is at a reduced rate relative to 1982-1995 (1.9 percent per year).[19]

Increases in yields for irrigated cereals in developing countries are expected to be of a similar proportion to increases in yields for rain fed cereals in the period 1997/99-2030 (annual increases of 0.9 and 0.8 percent, respectively). However, higher initial yields for irrigated cereals will result in greater absolute increases over this period. For developing countries collectively, average weighted yields for irrigated cereal production are expected to increase by 1.4 tones/ ha, compared with an increase of 0.5 tones/ha for rain fed cereals between 1997/99 and 2030.[20]

Irrigated agriculture is thereby forecasted to contribute significantly to increased future food production through both high and increasing crop yields.

In addition to increasing productivity, irrigation also enables expansion of the area under cultivation. In 1997/99, irrigation was used on 21 percent of arable land in developing countries collectively, though this was subject to considerable regional variation. In South and East Asia, irrigation was used on 39 and 31 percent of arable land, in the Near East and North Africa, 30 percent of arable land was irrigated, and in sub-Saharan Africa and Latin America (including the Caribbean), irrigation was used on only 2 and 9 percent of the arable area, respectively.[21]

Climate change is expected to affect agricultural production in developing countries, particularly through increases in temperature in arid regions (which will reduce the potential for crop production) and greater variability in the climate (which will cause increases in the frequency and duration of crop water stress). It will tend to increase local fluctuations in crop production and food supplies, particularly affecting food supplies and the incomes of poor people, and to increase national vulnerability to food insecurity. In certain regions, the effects could be significant even in the next few decades. For example, climate change could cause a 2-3-percent decline in cereal production in Africa by 2020 or 2030. Assuming that other factors remain constant, this would increase the number of people at risk of hunger by 10 million.[22]

Demand for food is not met solely by domestic production in many developing countries; imports of food are required to varying extents. In 1997/99, cereal production represented 91 percent of demand for cereals (a total of 1 026 million tones) in developing countries. However, this aggregation hides regional extremes. In the Near East and North Africa, domestic cereal production represented 63 percent of demand. In sub-Saharan Africa and Latin America (including the Caribbean), it represented 82 and 88 percent of demand, respectively, and in East and South Asia, production met 95 and 102 percent of demand. Reliance on imports is forecast to increase. In 1997/99, cereal imports

[19] *Bruinsma, 2003*
[20] *Bruinsma, 2003*
[21] *ibid, 2003*
[22] *ibid, 2003c*

accounted for 9 percent of demand in developing countries collectively and they are predicted to grow to 14 percent of demand by 2030.[23]

Poverty Alleviation

In an appropriate environment and with suitable planning (e.g. provision of training and credit), investment in irrigation schemes can alleviate poverty both directly and indirectly through stimulation of the rural economy.

Indeed, the purpose of many large scale schemes associated with the Green Revolution in Asia was more to do with addressing food security and poverty targets rather than direct commercial returns. This notion and practice persists. The IFAD "Report on Rural Poverty 2001" is clear in stating that irrigation schemes have direct benefits for poor people, given the required policy and institutional environment. Even if irrigation is not specifically targeted at poor beneficiaries, irrigation stimulates the agriculture sector of the rural economy indirectly through increased demand for agricultural inputs (including agricultural labor, services of local artisans who manufacture tools and equipment, seed and fertilizer) and the marketing of additional produce. Increased incomes in farming communities can create demand for non-agricultural goods and services (e.g. meat, processed foods, clothes, and repair of bicycles), many of which are marketed only locally and can be supplied by resource-poor individuals. The resultant stimulation of non-farm incomes can help to reduce absolute poverty in rural areas in the long term, and it can reduce relative poverty as long as the prevailing asset distribution is not too skewed.[24]

Increased food production from irrigated agriculture can confer nutritional benefits for farmers, their families and the local population (through increased food supplies). Irrigation can enable multiple cropping, which can smooth seasonal shortfalls in food supply and encourage the production of crops that contribute towards a more varied and nutritious diet. Improved nutrition can enhance quality of life, reduce illness, increase labor productivity, and improve the performance of children at school. Irrigated agriculture can also benefit the urban poor by keeping food prices low despite growing demand from increasing populations.[25]

However, irrigation can have a negative impact on the health of rural households through exposure to diseases transmitted by water-related vectors such as malaria. This is due to the fact that water is lodged for long time among canals and ditches. Moreover, in some environment, e.g. where land is not evenly distributed, economic benefits of irrigation may be received predominantly by wealthy farmers and aggravates inequalities in the distribution of resources and

[23] *Bruinsma, 2003*
[24] *Bruinsma, 2003*
[25] *IWMI, 2000 in FAO (2003c)*

wealth. Hence, the policy and institutional environments play critical roles in determining whether irrigation has positive impacts for poor people.

2.1.5 GINI COEFFICIENT

2.1.5.1 Overview

Gini coefficient is developed by an Italian statistician named Corrado Gini in the 1910s.

It is commonly used to indicate income inequality in a society. Gini Coefficient is a number which has a value between zero and one. As the value of the Coefficient rises, the higher the degree of income inequality in a society becomes.

The Gini coefficient is used to show the degree of income inequality between different groups of households in the population. It can also be used to show how inequality of incomes has been changing over a period of time.

Table 2: Gini Coefficient for some selected countries in the world

Gini Coefficient	Place	Survey year	Gini Coefficient	Place	Survey year
0.408	United States	2000	0.300	Ethiopia	2000
0.360	United Kingdom	1999	0.300	Ghana	1999
0.456	Russian Federation	2000	0.360	Italy	2000
0.571	Chile	2000	0.283	Germany	2000
0.432	Thailand	2000	0.325	India	1999-2000
0.446	Uruguay	2000	0.333	Canada	1998
0.445	Kenya	1997	0.258	Norway	1996
0.591	Brazil	1998	0.525	Hong Kong, China	2001
0.400	Turkey	2000	0.525	Peru	2000
0.398	Tunisia	2000	0.522	Argentina	2001
0.249	Japan	1993	0.425	Singapore	1998

Sources: The World Bank (2003)

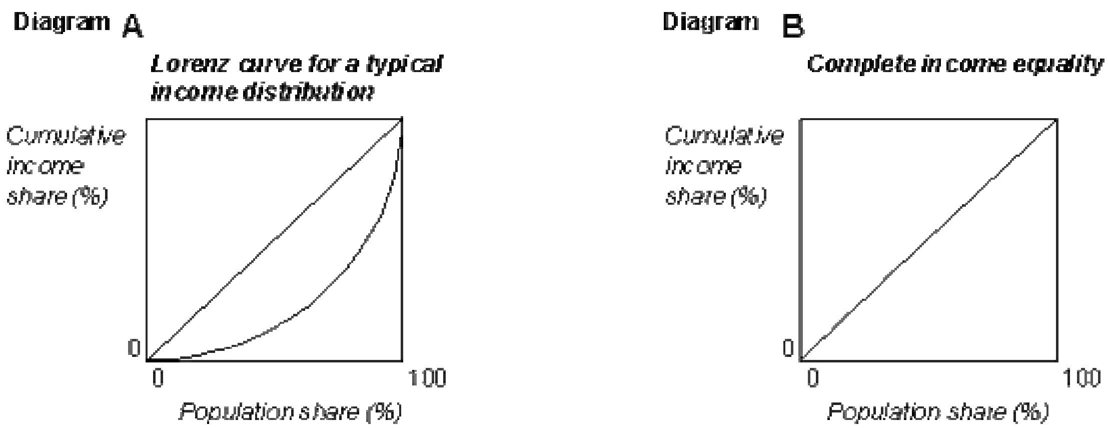
2.1.5.2 Measuring Inequality in Household Income: the Gini Coefficient

The most widely used summary measure of the degree of inequality in a household income distribution is the Gini coefficient. It represents an overall measure of the cumulative income share against the share of households in the population. The lower the value of the Gini coefficient, the more equally household income is distributed.

2.1.5.3 How is it calculated?

The derivation of the Gini coefficient is most easily stood by considering a Lorenz curve of the household income distribution (diagram A below). The first step is to rank the income of households in ascending order, and then to plot the cumulative share of household income against the cumulative share of households. There are two extremes. Complete equality, where income is shared equally among all households, results in a Gini coefficient of zero which is represented by a straight line (diagram B below). Complete inequality, where only one household has all the income and the rest have none, is given by a Gini coefficient of 100. In this case the curve comprises the horizontal axis and the right-hand vertical axis. The area between the Lorenz curve of the income distribution and the diagonal line of complete equality (the shaded area in diagram A), as a proportion of the triangular area between the curves of complete equality and inequality, gives the value of the Gini coefficient.

Figure 2:



Source: Measuring Inequality in Household Income: The Gini Coefficient from the National Statistics and ONS Home Page.

2.1.5.4 Expressing the Gini Coefficient Analytically

Various measures of inequality try to express in different ways a degree of inequality or variability as one number. Some of them are directly based on the Lorenz curve, and others are not. Gini coefficient is the best known and the most widely used measure of divergence based on the Lorenz curve. It is defined as an area between the diagonal and the Lorenz curve, divided by the whole area below the diagonal (equal to 1/2).

Analytically it can be expressed as

$$G_0 = 1 - 2 \cdot \int_0^1 \Phi(p)dp, \text{ where p=F(x)} \qquad (4)$$

Hanada (1983) showed that definition (4) together with (1)-(3) leads to

$$G_0 = 1 - \frac{1}{e(0)[l(x)]^2} \cdot \int_0^\infty [l(x)]^2 dx \qquad (5)$$

Sometimes it is impossible to get mortality data for the full range of ages. For example, mortality data could be unreliable at infant ages or at old ages. Often, in studies combining inter-individual inequalities with inter-group (social class) inequalities in length of life (see section 4), group-specific data on mortality are available only for a limited range of ages (e.g. working ages). Therefore, one might want to measure the inequality in age at death for ages above 15 (denoted as G_{15}) or between 20 and 65 (denoted as $G_{20|65}$).

Formula (5) can be re-written for the range of ages [*x*, *X*]

$$G_{x|X} = 1 - \frac{1}{e(x\,|\,X)[l(x)]^2} \cdot \int_x^X [l(t)]^2 dt, \qquad (5a)$$

where the temporary life expectancy is $e(x\,|\,X) = \frac{1}{l(x)} \int_x^X l(t)dt$.[26]

Gini coefficient varies between the limits of 0 (perfect equality) and 1 (perfect inequality). For a length-of-life distribution, it is equal to zero if all individuals die at the same age, and equal to 1 if all people die at age 0 and one individual dies at an infinitely old age.

There are several other ways to define Gini coefficient apart from the geometric definition (4). All of them are equivalent.[27] The definition by Kendall and Stuart (1966) is especially helpful for understanding the nature of this measure.

$$G_0 = \frac{1}{2\mu} \int_0^\infty \int_0^\infty |\,x - y\,|\, f(x) dx dy \qquad (6)$$

It suggests that Gini coefficient is simply a mean of absolute differences in individual ages at death (lengths of life) relative to the average length of life. If the population under consideration consists of *l*0 individuals, then the Gini coefficient is one-half of the average of absolute differences between all pairs of individual ages at death divided by the average length of life

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[26] *Arriaga (1984)*
[27] *Anand (1983)*

$$G_0 = \frac{1}{2(l_0)^2 e_0} \sum_{i=1}^{n} \sum_{j=1}^{n} | x_i - x_j | \cdot \qquad (6a)$$

This expression can be re-written in terms of the standard life table functions as

$$G_0 = \frac{1}{2(l_0)^2 e_0} \sum_{x=0}^{\omega} \sum_{y=0}^{\omega} d_x \cdot d_y \cdot | \bar{x} - \bar{y} |, \qquad (6b)$$

where $\bar{x}$ and $\bar{y}$ are the average ages at death for the elementary age intervals [x, x+1] and [y, y+1], respectively.

Formula (7) is simple to understand, but is not easy to apply in practical calculations. In this respect, it is preferable to use Hanada's formula (5). As a construct, this formula is quite similar to the one for life expectancy $e_0 = \frac{1}{l(0)} \cdot \int_0^{\infty} l(x)dx$. The task is to estimate the area under the curve $[l(x)]^2$ similarly to the area under curve $l(x)$ for life expectancy. This similarity helps to find a simple way for calculation of G_0 from discrete data.

Formulae (6), (6a) and (7) make it clear that Gini coefficient is a mean standardized measure. It varies from 0 to 1 and reflects relative inter-individual inequality. Such measures are also called indices. For some reasons one might be interested in absolute inter-individual differences in length of life. A respective measure, denoted G_0^{abs}, can be obtained from formulae (5) or (6) by removing life expectancy from the denominator. It is equal to the average inter-individual difference in length of life and is measured in years. The Hanada's formula (5) yields

$$G_0^{abs} = G_0 \cdot e(0) = e(0) - \frac{1}{[l(0)]^2} \cdot \int_0^{\infty} [l(0)]^2 dx \qquad (7)$$

2.2 EMPIRICAL LITERATURE

Without addressing the problem of poverty, it would be impossible to talk about other economic issues. This is why all countries in the world regardless of their stage of development give poverty the foremost priority in their agenda. However, literatures written in the area are still too few to address the core problem of poverty itself.

In this part of the paper we try to summarize few among the vast literatures on poverty and inequality written by various authors:

Abbi M. Kedir and Andrew McKay (2003*)* analyzed three waves of a unique and rich panel data set on 1500 households collected through the Ethiopian Urban Household Surveys from 1994 to 1997. Based on real total household expenditure per month as their preferred welfare indicator, their results indicate that there is a high level chronic poverty (25.9 %) more concentrated in central and northern cities. Households that experience transitory poverty constitute 23.0% of the total. Both the descriptive and econometric evidence indicate that chronic poverty has been associated with household composition, unemployment, lack of asset ownership, casual employment, lack of education, ethnicity, age and to a certain extent to female-headedness. Among ethnic groups, they found that the Tigres are less likely to be chronically as opposed to the Gurages.

The other research on poverty in Ethiopia is by Abbi Mamo Kedir in 1997 in the Ethiopian Journal of Economics. He used different econometric models (OLS, probit and multinomial logit selection) to analyse factors leading to poverty. The main emphasis of the study is to model determinants of standard of living in Addis Ababa using two-stage estimation techinique. In the first step, a multinomial logit model is applied to distinguish between three socio economic groups. The second stage regression, determinants of standard of living(i.e. total household expenditure per adult equivalent per month) are identified after incorporating the correction term for sample selectivity using the Lee-Heckman method. Among others, variables such as education, access to credit, employment status, gender, martial status and food shortage experience are significant determinants of welfare.

Mekonen (1999) attempted to address, simultaneously, two aspects of poverty in Ethiopia; determinants and dynamics of poverty. The study uses three rounds of urban household surveys conducted in 1994, 1995 and 1997. Consumption data was used to measure welfare and construct poverty profiles. In modeling determinants and dynamics of poverty, emphasis was placed on major socio-economic characteristics. Following Coulombe and McKay(1996) and Grooteart, et.al.,(1995), the determinants of living standards are broadly classified in to two: those that reflect household needs which includes household size and composition and those that determine the income generating opportunities available to the household such as education, employment and ownership of assets. The study by Mekonen is different from other poverty determinants studies which are based on cross-section data. It tries to capture the factors that determine changes in standard of living and the mobility of households in and out of poverty from panel data. The model is estimated using OLS and is derived from the standard utility maximization assumptions and uses real household expenditure per capita as money-metric measure of utility which takes in to account differences in household size and relative prices. Total household expenditure per adult equivalent is used as the dependent variable with exogenously determined household characteristics as regressors.

Qiuqiong Huang et al (2005) tried to understand the impact that irrigation in China has had on grain production and incomes, in general, and income and poverty alleviation in poor areas, in particular. Their analysis showed that irrigation contributes to increases in yields for almost all crops and in income for farmers in all areas. The importance of crop income in poor areas and the strong relationship between crop revenue and irrigation provides evidence of the importance of irrigation in past and future poverty alleviation in China. They also showed that in the majority of the villages that invested in new irrigation, returns are positive even after accounting for increases in capital and production costs.

Andrew J. Healy and Somchai Jitsuchon (2004) did a paper on Spatial Picture of Poverty and Inequality in Thailand: Estimates and a Demonstration. They provided the first comprehensive estimates of Thai poverty and inequality at levels below the changwat (province). They did this by combining a household survey, which has income and consumption data, with the 2000 Census, which is representative at the level of the individual. To improve the precision of their estimates, they proposed improvements to the methods previously applied in other settings. They produced estimates that correspond closely to those produced by the survey alone at the province level. In addition to passing this test, the standard errors on the district-level estimates of poverty and inequality are actually smaller than the changwat-level estimates that come from the household survey. Finally, they concluded by demonstrating the potential for this spatial decomposition to improve policy, and the usefulness of their results for directing resources in a much more effective way than was previously possible if policymakers want to reduce the poverty gap.

Almas Heshmati (2005) wrote a discussion paper on The Relationship between Income Inequality, Poverty and Globalization. This paper introduced two composite indices of globalization. The first is based on the Kearney/Foreign Policy magazine and the second is obtained from principal component analysis. They indicated the level of globalization and show how globalization has developed over time for different countries. The indices are composed of four components: economic integration, personal contact, technology and political engagement, each generated from a number of indicators. A breakdown of the index into major components provided possibilities to identify sources of globalization at the country level and associated it with economic policy measures. The empirical results showed that a low rank in the globalization process is due to political and personal factors with limited possibility for the developing countries to affect. The high ranked developed countries shared similar patterns in distribution of various components. They also used the indices in a regression analysis to study the causal relationships between income inequality, poverty and globalization. They concluded that inequality is negatively correlated to globalization, and globalization reduces poverty.

Xavier Sala-i-Martin (2002) has written a working paper on The Disturbing “Rise” Of Global Income Inequality. He used aggregate GDP data and within-country income shares for the period 1970-1998 to assign a level of income to each person in the world. He estimated the Gaussian kernel density function for the worldwide distribution of income. He then computed world poverty rates by integrating the density function below the poverty lines. The $1/day poverty rate has fallen from 20% to 5% over the last twenty five years. The $2/day rate has fallen from 44% to 18%. There are between 300 and 500 million less poor people in 1998 than there were in the 70s.He also estimated global income inequality using seven different popular indexes: the Gini coefficient, the variance of log-income, two of Atkinson’s indexes, the Mean Logarithmic

Deviation, the Theil index and the coefficient of variation. All indexes showed a reduction in global income inequality between 1980 and 1998. In addition to this, he found that most global disparities can be accounted for by across-country, not within country, inequalities. Within-country disparities have increased slightly during the sample period, but not nearly enough to offset the substantial reduction in across-country disparities. The across-country reductions in inequality are driven mainly, but not fully, by the large growth rate of the incomes of the 1.2 billion Chinese citizens. Unless Africa starts growing in the near future, he projected that income inequalities will start rising again. If Africa does not start growing, then China, India, the OECD and the rest of middle-income and rich countries diverge away from it, and global inequality will rise. Thus, the aggregate GDP growth of the African continent should be the priority of anyone concerned with decreasing global income inequality.

CHAPTER THREE

DESCRIPTION OF THE MODEL

3.1 MODELLING IRRIGATION, POVERTY AND INEQUALITY

In this research paper, we use the following model to show the link between irrigation, poverty and inequality.

3.1.1 MODELING IRRIGATION AND INCOME

We follow the standard approach in the literature on permanent income analysis[28] and on income inequality in rural China specifically.[29] In these studies, the determinants of income can be analyzed by making income a function of a set of household and village characteristics, including household irrigated area.

Following this literature, our basic model is:

$$y_{hv} = \alpha + \gamma D_{hv} + \mathbf{X_{hv}}\boldsymbol{\beta} + \mathbf{Z_v}\boldsymbol{\delta} + \mu_v + \varepsilon_{hv} \qquad (1)$$

where;

y_{hv} denotes total income, cropping income, off-farm income or other income (in per capita terms) for household h in village v.

$\boldsymbol{X_{hv}}$ is a matrix of household characteristics including household size, dependency ratio and literacy of household's head, degree of land fragmentation, proportion of good quality land and proportion of output (harvest) affected by negative shocks. Cultivated land per capita is included to control for land as a fixed input. We also include several variables such as household

[28] Datt 1998; Paxson 1992

[29] Benjamin *et al.* 2000; Morduch and Sicular 2002

agricultural assets, self-employed business assets, and non-productive assets (in per capita terms), to control for factors including household's ability to adopt new technologies.

Zv denotes the observable village characteristics including a village's topography, its distance from the county seat, and the proportion of villagers that worked off-farm. Equation (1) also includes a term, μ_v, which represents all other village fixed effects that vary by village and are difficult to observe or measure (e.g., the economic environment of the village, certain climatic and/or agronomic factors that affect village-wide yields and prices, etc.). After holding $\boldsymbol{X_{hv}}$ and ***Zv*** constant, γ can be interpreted as our parameter of interest, measuring the effect of area of irrigated land per capita denoted by D_{hv}.

This approach enables us to use the village-level data on employment, infrastructure and topography, increasing the degrees of freedom and allowing us to estimate the importance of these village characteristics. However, it is possible that we have omitted village-level variables that, although unobserved, may affect income and may be correlated with irrigation. One such variable is weather variation in the village. In such a case, we could have an omitted variables problem and estimates of γ would be inconsistent. If this is the case, one solution is to include a set of village dummy variables that capture all of the observed and unobservable village effects. Casting the problem in this way (henceforth, the fixed effects model), however, means that we cannot separate the effect of specific village characteristics (***Zv*** and μ_v) from other village fixed effects since all are captured by the village dummy variables. In addition, since input and output prices are almost surely the same within each village, the effect of prices on income is also grouped with other village fixed effects and cannot be separated out. If we adopt this approach, the fixed effects model that we estimate is:

$$y_{hv} - \bar{y}_{hv} = \gamma(D_{hv} - \bar{D}_{hv}) + (\mathrm{X}_{hv} - \bar{\mathrm{X}}_{hv})\boldsymbol{\beta} + (\varepsilon_{hv} - \bar{\varepsilon}_{hv}) \qquad (2)$$

where $\overline{y}_{hv}$, $\overline{D}_{hv}$, $\overline{X}_{hv}$ and $\overline{\varepsilon}_{hv}$ are the averages of variables at the village level.

3.1.2 MODELING IRRIGATION AND POVERTY

To study more carefully the effects of irrigation on poverty, we use a simulation approach in order to assess the change in poverty incidence arising from a change in a specific factor. To do so, we follow Datt (1998) and Gibson and Rozelle (2003) cited in Q. Huang et.al (2005) and use parameters from a regression analysis of the determinants of total income to create a simulation framework. More specifically, the basic model is of (log) income per capita, *yhv*, deflated by the poverty line, *c*, a ratio known as the "welfare ratio":

$$\ln(y_{hv} / c) = \alpha^{'} + \gamma^{'} D_{hv} + X_{hv}\beta^{'} + Z_{v}\delta^{'} + \mu_{v}^{'} + \varepsilon_{hv}^{'} \qquad (3)$$

where ε'_{hv} is independently and identically distributed normal random variables with zero means and constant variance, σ_v. Note that although we use a semi-log specification in equation (3), equations (1) and (3) are in essence the same equation except for the monotonic transformation of the dependent variable.

Normalizing income per capita by the poverty line implies that $\ln\left(y_{hv} / c\right)<0$ for poor households and the probability of the *h*th household being poor can be derived from:

$$\Pr ob[\ln(y_{hv} / c) = \Phi[-(\alpha^{'} + \gamma^{'} D_{hv} + X_{hv}\beta^{'} + Z_{v}\delta^{'} + \mu_{v}^{'}) / \sigma_{v}] \qquad (4)$$

We adopt the same approach as in estimating equation (1) and the fixed effects model we estimate is:

$$\ln\left(y_{hv} / c\right) - \overline{\ln\left(y_{hv} / c\right)} = \gamma^{'}\left(D_{hv} - \overline{D}_{hv}\right) + \left(X_{hv} - \overline{X}_{hv}\right)\beta^{'} + \left(\varepsilon_{hv}^{'} - \overline{\varepsilon}_{hv}^{'}\right) \qquad (5)$$

where $\overline{\ln\left(y_{hv}/c\right)}$, $\overline{D}_{hv}$, $\overline{X}_{hv}$ and $\overline{\varepsilon}'_{hv}$ are the averages of variables at the village level. After we obtain consistent estimates of γ' and β' by estimating equation (5), we then plug them back into equation (3):

$$\ln(\hat{y}_{hv}/c) = \hat{\gamma}' D_{hv} + X_{hv}\hat{\beta}' + [\underbrace{\alpha' + Z_v\delta' + \mu_v'}_{\hat{\alpha}'}] \qquad (6)$$

where the terms in bracket is estimated as one single parameter, $\hat{\alpha}'$, the village fixed effect, and is captured by the coefficients on the village dummy variables.

In the simulation, the probability of the *h*th household being poor is calculated as:

$$\Pr ob\left[\ln\left(y_{hv}/c\right)<0\right] = \Phi\left[\frac{\ln\left(\hat{y}_{hv}/c\right)}{\hat{\sigma}_v}\right] \qquad (7)$$

A weighted average of the household probabilities of being poor gives the predicted incidence of poverty, where the weights are the household sampling weights in terms of household size.

Once the simulation is done, it is possible to look at the effects of increasing irrigated land on poverty reduction. That is, the incidence of poverty may fall/rise by certain percentage points if all non-irrigated land were converted to irrigated land. Thus, the simulation work will clearly show us the effect of irrigation on poverty reduction.

3.1.3 MODELING IRRIGATION AND INEQUALITY

To analyze the impact of irrigation on inequality, we decompose inequality in two ways:

by *source of income* (cropping income from irrigated plots, cropping income from non-irrigated plots, off farm income and other income); and by estimated *income flows due to specific household characteristics* (e.g., irrigated land area per capita and the education level of the household's labor force). Our methodology is similar in both cases. We decompose the Gini coefficient for total household income as a weighted sum of the inequality levels of incomes from different components, with the weights being functions of the importance of each component and the correlation of each component with total income. For example, if the income contributed by irrigated land accounts for a large share of total income and is itself highly unequally distributed, it is likely to increase the total income inequality. However, if income from a component is negatively correlated with total income (i.e. this component is more concentrated in the hands of poor farmers), then larger shares of that factor might help equalize total income.

We first decompose the total income Gini coefficient by income source. We begin by noting that if y_k is income from source *k* (e.g., irrigated plots), then total household income, y_0, is:

$$y_0 = \sum_{k-1}^{k} y_{k,} k = 1,..., K. \quad (8)$$

Note the subscripts *h* and *v* are suppressed here. Following the method suggested by Stuart (1954) and Pyatt, Chen and Fei (1980) and Lerman and Yitzhaki (1985) cited in Q. Huang et al (2005), we can write the Gini coefficient for total household income per capita, G_0, as:

$$G_0 = \sum_{k-1}^{k} S_k G_k R_k \quad (9)$$

where S_k is the share of y_k in y_0; G_k is the Gini coefficient of y_k; and R_k is the Gini correlation between y_k and the distribution of y_0 and is defined as:

$$R_k = \text{cov}(y_k, F(y_0)) / \text{cov}(y_{k,} F(y_k)) \quad (10)$$

where $F(y_0)$ and $F(y_k)$ are the cumulative distributions of total household income and income from source *k* respectively.

If income component *j* increases by a factor of *e,* such that $y_j(e) = (1+e)y_j$ *for all households*, the marginal effect of this percentage change on total income inequality is

$\partial G_0 / \partial e_j = S_j (R_j G_j - G_0)$ $\qquad j = 1,2,\ldots,K.$ (11)

where S_j, R_j, G_j and G_0 are measured prior to the marginal income change. Dividing equation (11) by G_0, we obtain:

$(\partial G_0 / \partial e_j)/G_0 = (S_j R_j G_j)/G_0 - S_j$ $\qquad j = 1,2,\ldots,K.$ (12)

The relative effect of a marginal percentage change in source-*j* income on the Gini coefficient for total income (elasticity of total income inequality with respect to income source *j*) equals the relative contribution of source *j* to overall income inequality minus the share of source *j* in total income.

The limitation of decomposing inequality by income flows can be overcome by using a regression-based approach to decompose total income inequality by income flows attributable to specific household characteristics. This approach follows the work of Taylor (1997) and Morduch and Sicular (2002) cited in Q. Huang et al (2005). In this approach, the estimated income flows contributed by characteristics, such as, area of irrigated land, level of education and age, are calculated using the estimated parameters ($\hat{\gamma}$ and $\hat{\beta}$) given by the regression results from equation (2), and these flows constitute the various components of total income. By construction, total income is the sum of these flows:

$$y_{hv} = \hat{\gamma} D_{hv} + \mathrm{X}_{hv}\hat{\beta} + \hat{\alpha}_v + \hat{\varepsilon}_{hv} \qquad (13)$$

Where $\hat{\alpha}_v$ is the estimated village fixed effect that is equivalent to the estimate of the term, $\alpha + \mathrm{Z}_v \delta + \mu_v$, in equation (1). The shares of income flows from the area of irrigated land per capita and other household characteristics take the form $\frac{\hat{\gamma} D_{hv}}{y_{hv}}$ and $\frac{\mathrm{X}_{hv}\hat{\beta}}{y_{hv}}$, respectively. The decomposition by income flows uses the same approach as the decomposition by income sources except that each *yk* is replaced by estimated income flows $\hat{\gamma} D_{hv}$, $\mathrm{X}_{hv}\hat{\beta}$, $\hat{\alpha}_v$ and $\hat{\varepsilon}_{hv}$.

3.1.4 CALCULATING THE GINI COEFFICIENT OF INEQUALITY

Let be a vector of incomes, with extreme values $y_{\min}$ and $y_{\max}$, mean μ, and cumulative distribution $F(y)$. It is well known that the Gini coefficient of inequality is:

$$G = \{\int_{y_{\min}}^{y_{\max}} F(y)[1-F(y)]\}/\mu \qquad (1)$$

Suppose that the observed data are in increasing order, with i'th value y_i. Then Ogwang[30] (2000) notes that the Gini coefficient can also be expressed as:

$$G = [(n^2-1)/(6n)](\hat{\beta}/\bar{y}), \qquad (2)$$

where $\bar{y}$ is the sample arithmetic mean of y, $\hat{\beta}$ is the OLS estimator of β in the model

$$y_i = \alpha + \beta i + \varepsilon_i$$

and the ε_i's are zero-mean, independent, and homoskedastic errors.

3.2 A MODEL FOR CALCULATING POVERTY LINE

As described in the literature part of this paper, we have basically two approaches for calculating poverty lines namely: objective poverty lines and subjective poverty lines. Under the objective poverty lines, we have two methods: the food-energy intake and the cost of basic needs methods. We could also find distinctions under the subjective poverty lines. For the sake of this paper, we choose the food-energy intake or also known as the cost of calories approach used in 'Food Poverty Profile Applied to Kenyan Smallholders' by Joel Greer and Erik Thorbecke in October 1986.

[30] Ogwang, T. (2000). 'A Convenient Method of Computing the Gini Index and its Standard Error', *Oxford Bulletin of Economics and Statistics*, Vol. 62, pp. 123-29.

> Calorie-based poverty lines are widely used around the world. The association with food appears to be attractive, in part because poor people do indeed spend much of their budget on food, but perhaps also because there is more political support for anti-poverty programs that involve food than for measures based on goods that are seen as less meritorious. The right to food is more compelling than the right to other consumer goods. The nutritional basis, and the involvement of nutritional scientists in setting the norms, also appears to add legitimacy to the lines and the counts that are based on them.[31]

Food poverty can be defined generally as a condition of lacking the resources necessary to acquire a nutritionally adequate diet. The food poverty line is the minimum amount of food an individual must consume to stay healthy. It can be measured in terms of the nutritional characteristics of the foods (e.g., calories), the quantities of the foodstuffs themselves or the monetary value of the foods. Sen (1978) has provided a strong argument for using a monetary poverty line: it allows the individual the freedom to choose how or even whether to satisfy his or her basic needs. Individuals who have the ability to meet their minimum needs should not be considered poor even if they do not do so. The food poverty line we adopt is the minimum food expenditure necessary for a person with the accepted and typical regional food consumption pattern to consume a nutritionally adequate diet.

> Focusing on food poverty allows use of the nutrient recommended daily allowances (RDAs) as the basis for setting the poverty line. Despite large interpersonal and intertemporal variations in nutrient needs, the RDAs can be used because they represent typical needs based on sampling large groups of people. Only those nutrients likely to be consumed in inadequate quantities need be considered. Nutritionists have found that with only a few exceptions, individuals eating sufficient calories automatically meet their protein needs. Similarly, many vitamin and mineral deficiencies would be eliminated with no modification of typical dietary patterns if sufficient calories were consumed. As a result the caloric RDA can generally be used for food poverty measurement purposes as the single nutrient requirement.[32]

> Estimating food poverty - in contrast with the more general concept of poverty - is of interest in its own right, e.g., as a measure of the success of national food policies. It may also be seen as a proxy variable for estimating total poverty because of its operational advantages: (1) it is simpler to define what constitutes food poverty and therefore to calculate the food poverty line, (2) its data needs are less than those required to estimate

[31] Deaton, A. and Muellbauer, J. 2003

[32] Joel Greer and Erik Thorbecke, 1985

overall poverty, (3) food expenditure data arc generally among the more accurate components collected by household budget surveys, and (4) there are physiological signs of malnutrition so the results can be checked against objective standards.[33]

Several previous methods which have been used to calculate food poverty lines are reviewed in Randolph (1982). She finds serious faults with all of them. However, in this thesis I have preferred to use a method of calculating food poverty line suggested by Joel Greer and Erik Thorbecke, 1986. They proposed a new method which is conceptually and computationally simple, does not require an excessive sample size, and does not pre-impose a researcher's or bureaucrat's subjective notion of what constitutes a palatable, but inexpensive diet. In essence, it requires only two pieces of information for each individual:[34] calorie consumption C_j and food expenditure variable X_j. This latter variable measures both purchased food and the imputed value of food consumption out of own production. Given information on food expenditure and calorie consumption, it is possible to estimate the cost of acquiring a given number of calories by using the cost-of-calories function which, in log linear form, is

$$\ln X = a + bC \qquad (1)$$

The poverty line Z is the estimated cost of acquiring the calorie RDA, R.

$$Z = e^{(\hat{a}+R\hat{b})}, \qquad (2)$$

where $\hat{a}$ and $\hat{b}$ are the coefficient estimates of a and b, respectively, from eq. (1).

Eq. (1) approximates an exactly determined but unknown relationship between X and C. It is based on two fundamental assumptions:

(1) All individuals face identical prices; and

(2) There is a common dietary taste pattern.

[33] ibid, 1985

[34] Because expenditure and consumption surveys typically collect data by household, in actual practice j represents households and Cj and Xj are expressed in per adult equivalent terms. This of course requires information on the household's size and composition in order to calculate the number of adult equivalents.

CHAPTER FOUR

GENERAL BACKGROUND AND DESCRIPTION OF THE STUDY

4.1 Background of the Study Area

4.1.1 A Brief Outline of Awi Zone

Awi administrative zone is one among the eleven zones of the Amhara National Regional Government (ANRG). The Zone has been established based on the constitution of Ethiopia in 1994 G.C. Its area is 857,886 hectares of land and covers 5.2 percent of the region. It constitutes 159 rural and 21 urban Kebeles.

The Zone is adjacent to West Gojjam in the East and North; to Oromia National Regional Government in the South; to North Gonder Zone in the North West and to Benishangul Gumuz National Regional Government in the West. Its geographical setting is briefly shown below:

Altitude: ranges from 1900 to 3300 meters above see label.

Climate: Dega-85% and the remaining 15% is Woina Dega

Temperature: Average-19 ^oC

Rainfall: Average-2206 mm

The total population of the Zone is estimated to be 717085 based on the 1994 Ethiopian census from which only 9% is living in urban centers and the rest majority is rural resident. The table below shows the population of Awi Zone with sex and residency based on the 1994 census.

Table 3: Population of Awi Zone with sex and residency

	Male	**Female**	**Both**
Urban	29411	35821	65232
Rural	327827	324026	651853
Total	**357238**	**359847**	**717085**

Souce: CSA 1994 Ethiopian census

4.1.2 A brief Picture of Banja Woreda

Banja Woreda is found in Amhara National Regional Government under Awi Zone. It has a total population of 175 858 in the year 2000 predicted based on the 1994 Ethiopian Census. From the total of 35 kebeles in Banja, 31 are rural and the rest 4 are urban kebeles. In the Woreda, 7% of the population is urban based while 93% of the residents are living in rural areas.

Table 4: Population of Banja with sex and residency (1994 census)

	Rural	Urban	Total
Male	82,096	5,512	87,608
Female	81,438	6,812	88,250
Total	**163,534**	**12,324**	**175,858**

(Source: CSA 1994 Ethiopian census)

Table 5: Population of Banja Woreda categorized based on Religion and Sex

Category	All persons	Orthodox	Protestant	Catholic	Muslim	Others	Traditional	Not stated
Urban	**9866**	**9804**	**52**	**1**	**9**	**-**	**-**	**-**
Male	4367	4338	23	-	6	-	-	-
Female	5499	5466	29	1	3	-	-	-
Rural	**142084**	**141948**	**87**	**1**	**17**	**2**	**3**	**26**
Male	71278	71217	38	-	9	-	-	14
Female	70806	70731	49	1	8	2	3	12
Urban+Rural	**151950**	**151752**	**139**	**2**	**26**	**2**	**3**	**26**
Male	75645	75555	61	-	15	-	-	14
Female	76305	76197	78	2	11	2	3	12

(Source: CSA 1994 Ethiopian census)

In the table above (Table 3), the rural population of Banja woreda accounts 93.5 percent while the remaining population is leading life in four urban centers of the woreda namely Tilili, Kosober, Kosa and Injebara. Ethiopian Orthodox Church followers account 99.87 percent of the woreda population followed by Protestant, Muslim and Catholic religion followers. Moreover, male and female populations of the woreda are more or less equal with female population accounting 50.2 percent.

Table 6: Population of Towns in Banja Woreda categorized based on Religion and Sex

Towns in Banja	Category	All persons	Orthodox	Protestant	Catholic	Muslim	Others	Traditional	Not stated
Injebara	**Both**	**754**	**754**	**-**	**-**	**-**	**-**	**-**	**-**
	Male	326	326	-	-	-	-	-	-
	Female	428	428	-	-	-	-	-	-
Kosober	**Both**	**2679**	**2626**	**46**	**1**	**6**	**-**	**-**	**-**
	Male	1164	1142	19	-	3	-	-	-
	Female	1515	1484	27	1	3	-	-	-
Kosa	**Both**	**1327**	**1326**	**1**	**-**	**-**	**-**	**-**	**-**
	Male	609	608	1	-	-	-	-	-
	Female	718	718	-	-	-	-	-	-
Tilili	**Both**	**5106**	**5098**	**5**	**-**	**3**	**-**	**-**	**-**
	Male	2268	2262	3	-	3	-	-	-
	Female	2838	2836	2	-	-	-	-	-

(Source: CSA 1994 Ethiopian census)

According to the report by CSA (1994), Banja woreda has for urban centers. Among them, Tilili is the leading urban town with a population of 5106 in Banja woreda followed by Kosober. Besides, the report also shows that the Ethiopian Orthodox Church is the dominant religion in the towns of Banja woreda. In all of the towns, the number of female population exceeds that of male population.

4.1.3 GIS Map of the Study Area

The thesis coverage is limited to Banja Woreda in Awi Zone of the Amhara Region. In the above tables, we have tried to show a brief description of the demographic features of the Woreda. Below are geographical maps showing the relative location of Banja woreda in Ethiopia, Amhara Region and Awi Zone.

Figure 3: *A Figure demonstrating the relative location of the Amhara Region in Ethiopia and that of Banja Woreda in Amhara Region*

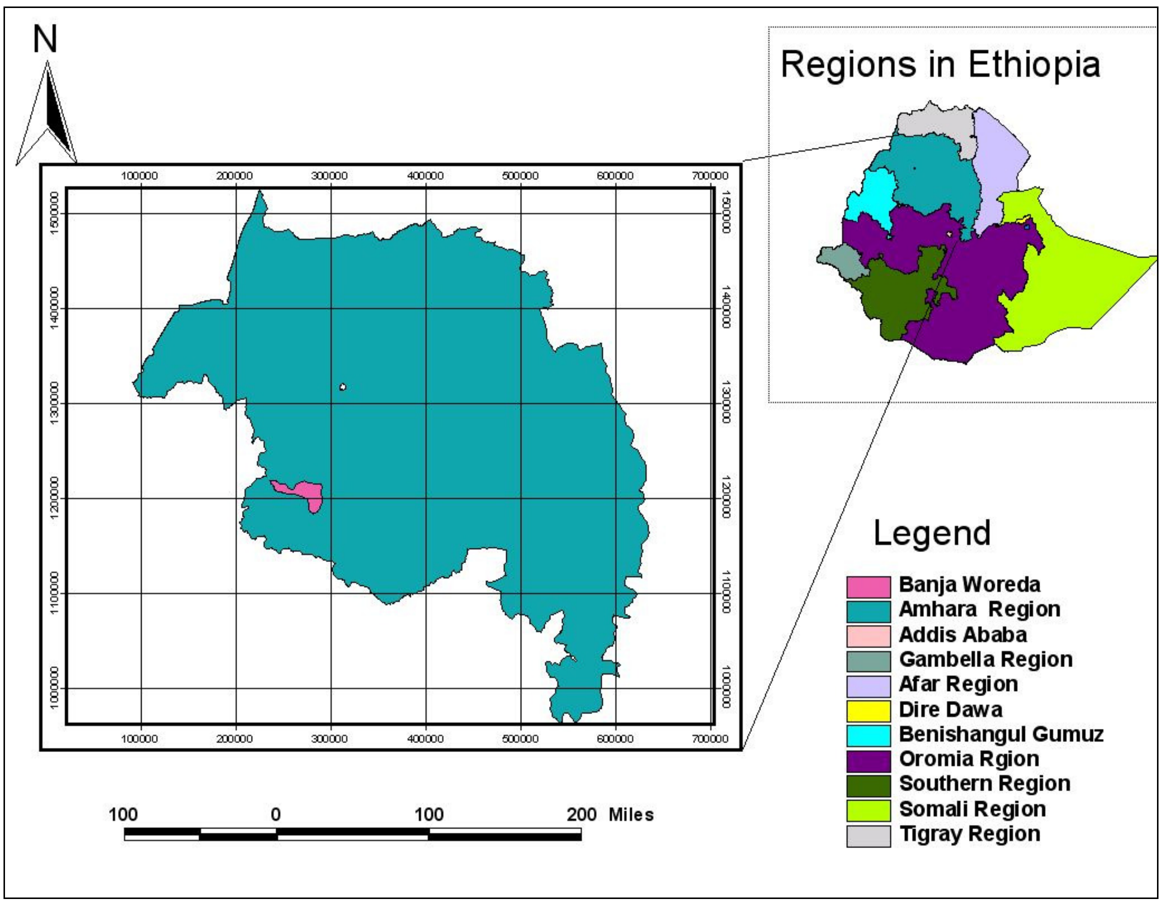
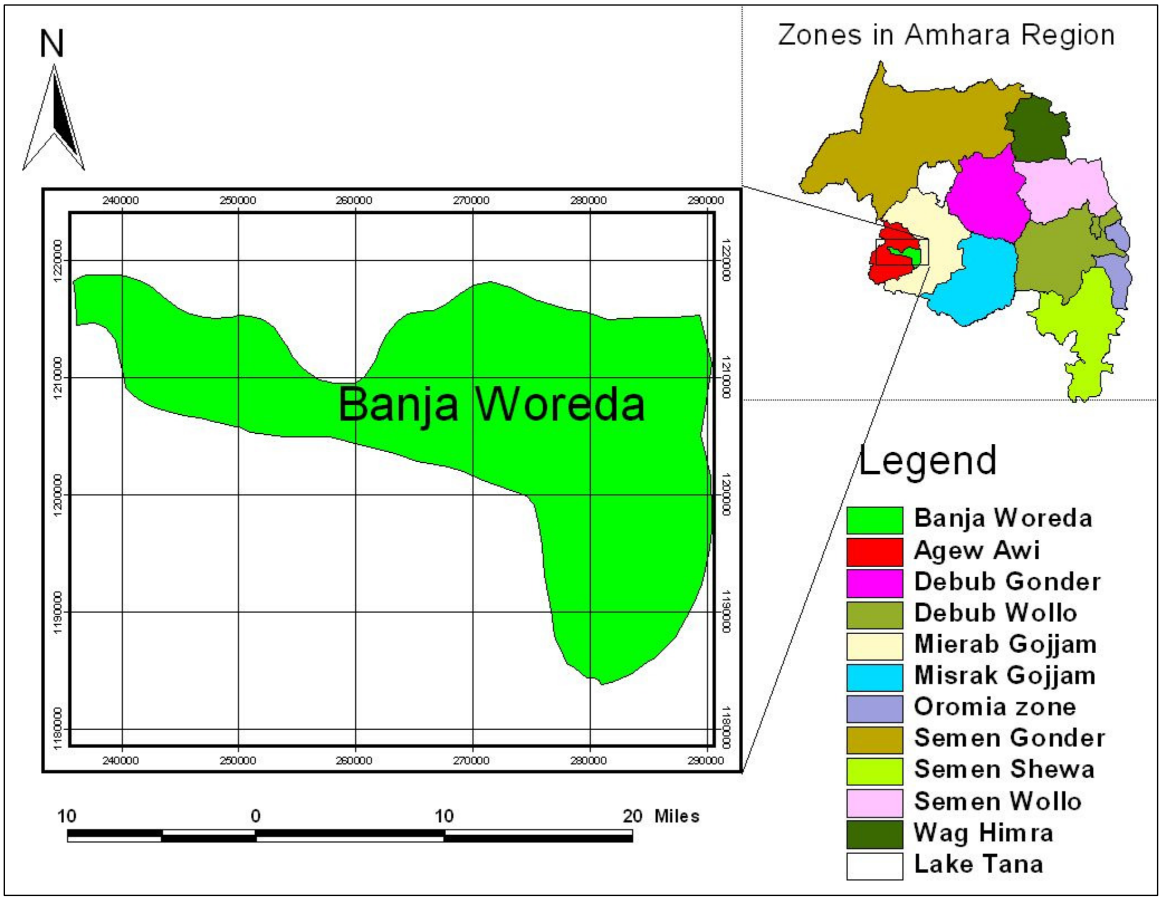


Figure 4: *A figure showing the location of Awi Zone in Amhara Region in general and Banja Woreda in particular*



4.2 Methodology of the Study

This research has been conducted to evaluate the effects of irrigation on poverty and income distribution in rural households of Banja woreda-Amhara Region. Due to financial, material and time constraints, the survey was done for few selected rural kebeles in the woreda. Five rural kebeles were selected from the total of 31 in the woreda.

Sampling Methods and Procedures

I have selected five rural villages using purposive sampling methods. This method was chosen because most rural villages of the woreda are not irrigated hence, for the sake of the analysis, two of the five selected kebeles are intended be irrigated while the other two must be non-irrigated and the rest one was anticipated to be half-irrigated and half non-irrigated.

In the selection of sample households, a random sampling method was employed to give households an equal chance of being selected in the sample.

The Woreda Administration Office has helped me a lot in creating a link with the intended study sites. As a preliminary work, a pilot survey on 15 households was conducted in the study area. Based on the lessons drawn from the survey, some improvements have been carried out on the questionnaire designed.

For the main survey, I selected 2 development agents from each kebeles and gave them orientation for two days on the aim of the research, the way the questionnaire was designed, the method of interviewing and other important information and procedures for the interview. On the next seven consecutive days of the week, the interview was conducted on 30 households from each kebeles namely Askuna Abo, Senkesa, Zufare, Askuna Agza and Abssela Warda.The former two kebeles are irrigated where as the later two are non-irrigated. Zufare is selected as a village that is half-irrigated and half non-irrigated.

As indicated above, the Woreda has four urban centers (Kosober, Tilili, Kosa and Injebara) and thirty one rural kebeles. The administrative town of the woreda is Kosober. Two of our study sites Askuna Agza and Abssela Wareda are found to the south of Kosober and their common market place is Tilili town, around 20 kms from the adminstrative town. On the other hand, Senkesa, Askun Abo and Zufare are found to the west of the administrative town and their common market place is Kosober. These study villages share common features of being rural areas. However, they are distinct from each other in many ways. Senkesa, Askuna Abo and Zufare are found along the gravel road to Benishangul Gumuz Regional State while the other two sites are found along the asphalted road to Addis Ababa. The Woreda is a very wide one with a plan of splitting it in to two Woredas by the Regional State. Each village has its own distinct features of eduction, health, communication and other social facilities. They have also different demographic and geographical settings. Due to these reasons, I have preferred Ordinary Least Squares with fixed effects at the village level for analyzing the determinants of income of households. In addition to this, the probit model is employed to study the effect of irrigation in poverty incidence using household size as a sampling weight. Finally, the Gini coefficient has been used for analyzing the impact of irrigation on income distribution. At this point it is important to note that Stata and Microsoft Excel are the principal softwares employed for analyzing the data collected for the study.

CHAPTER FIVE

5. Estimation Results and Discussion

5.1 Irrigation and Income

Compared to other countries, the proportion of Ethiopia's area that is irrigated is very low. Based on MOFED (2002), during the program period (2002/03-2004/05) irrigation program aims to develop a total of 29,043 hectare of new land, which bring the total area under irrigation to 226,293 hectare by the end of 1997 E.C making 114,390 household beneficiaries. The small scale irrigation schemes for the period (2002/03-2004/05) is expected to cover an area of 23,823 ha benefiting about 93,510 households. Even if there is no exact statistical data in the distribution of irrigation in the study area, the figure will not be different from the country's reality.

In the table below, I have compared the different levels of irrigated land per capita of households with the sources of incomes.

Table 3: Annual Household income per capita and area of irrigated land per capita

Irrigated land per capita(ha)	No. household	Total household income per capita(Birr)	Cropping income per capita(Birr)	Off-farm income per capita (Birr)	Other income per capita (Birr)	Total land per capita (ha)
Banja	150	4421.335(100%)	3805.97(86.08%)	249.6867(5.65%)	365.6787(8.27%)	1.524794
0 ha(Non-irrigated)	75	2485.104(100%)	1960.84(78.9%)	283.8933(11.4%)	240.3707(9.7%)	1.115367
0<x≤0.5 ha	36	4854.097(100%)	4500.653(92.7%)	140.528(2.9%)	212.9167(4.4%)	1.313194
0.5<x≤1 ha	18	6030.667(100%)	5036.222(83.5%)	338.8889(5.6%)	655.556(10.9%)	1.271806
Above 1 ha	21	9191.357(100%)	8148.452(88.7%)	216.2857(2.4%)	826.619(8.9%)	2.39881

The data show that the amount of irrigated land per capita is strongly correlated with annual cropping income (Table 3, column 3). Compared to households without irrigated land (row 2), annual per capita cropping income is 129.5 percent higher (4500.653 vs 1960.84) in households that have irrigated land holdings of up to 0.5 ha per capita (row 3). Besides, compared to households with irrigated land of 0<x≤0.5 ha, annual cropping income is 12 percent higher (5036.222 vs 4500.653) in households that have irrigated land holdings of 0.5<x≤1 ha per capita.

This is true despite the fact that the average household's cultivated land per capita is only 1.27 ha in the households with irrigated land of 0.5<x ≤1 ha per capita which is less compared to 1.31 ha of cultivated land in households with 0<x≤0.5 ha irrigated land per capita. Hence, we see that cropping income per capita continues to rise as irrigated land per capita increases.

The data also show that as irrigated land per capita increases, cropping income becomes a more important source of household income (Table 3, column 3 – see figures in parentheses). For example, cropping income accounts for about 78.9 per cent of total income for households without irrigated land. The share of income from cropping grows as irrigated land per capita increases except for the share of income from irrigated land per capita of 0<x≤0.5 ha, which is exceptionally high. For those with more than 1 hectare irrigated land per capita, cropping income contributes to 88.7 per cent of total household income.

Total income per capita shows the same monotonically increasing relationship with irrigated land area as does per capita cropping income (Table 3, column 2). Households with irrigated land of above 1 hectare per capita have a relatively high average annual income (9191.357 Birr per capita). By contrast, those with irrigated land of 0 hectares per capita have total income that reach, on average, only 2485.104 Birr per capita.

After examining column 2 of Table 3, we can draw one of two conclusions: (i), irrigation is a significant factor in determining total income; or (ii), we are only observing two-way correlations and the true relationship between irrigation and total income could be masked by correlation between other factors. In order to answer the question of whether irrigation affects household income we need to hold other factors constant by using multivariate analysis.

5.1.1 Definition and Relation of Variables

Endogenous Variables:

- **cropinc:** It refers to cropping income. It is a part of total household income that includes proceeds from crop sales less expenses. Profits from processed crops are also included in this category.
- **offinc:** It denotes off-farm income of households. It is a component of total household income that includes all income from businesses run by households, wages from a household member's off-farm job and migrant remittances.
- **otherinc:** It symbolizes other incomes of households. It includes livestock income, income from gifts(non-remittances), rental income, income from subsidies and pensions, income from interest, income from asset sales, net value of commercial agricultural commodities(e.g., vegetable and fruit), value of crop subsidiaries (e.g., fodders), net value of processed crop products, and miscellaneous income.
- **totinc:** It designates the total income of households. It is the grand figure of all revenues generated by household members from different sources. It is the sum of the above three types of incomes.

Exogenous Variables:

- **areairrig:** It symbolizes area of irrigated land per capita which is assumed to be positively related to household incomes.
- **hhsize:** It refers to the total number of members living in the household.
- **depratio:** It designates the dependency ratio that exists in households. It captures the effect of dependency that comes from non-working household members on

that of the labor force. Dependency ratio is thought to be negatively related to income of households.

- **literacyhead:** It stands for the literacy of household head. In this study, a person is considered to be literate if he/she is able to read and write. Theoretically, it is an important factor for the amount of household incomes and is assumed to be positively related to household incomes.
- **nuplot:** It is a short name for number of plots of a household. It is a proxy for measuring the degree of land fragmentation. In the literature, it is taken to be negatively related to household incomes.
- **propquality:** It denotes the proportion of a household's land with good quality and it is clearly thought to be a positive factor of land productivity and so agricultural household's income.
- **propshock:** It symbolizes the proportion of output (harvest) affected by negative shocks in the past Belg and Meher seasons. It is expected to be negatively related to household's income.
- **cultivated:** It is a short name for cultivated land per capita of households. It includes all plots of land used for agriculture in the past Meher and Belg seasons. Cultivated land per capita is theoretically positively related to household incomes.
- **nonlagriassets:** It includes all assets that are categorized under agricultural activities but different from land and livestock resources. They are considered to be positively related to household incomes.
- **selfbusassets:** It refers to self business assets of households such as weaving machines, mills, machines for wood works and the like. It is considered to increase household's income especially off-farm income.

- **nonprodassets:** It is a short name for assets that are not directly employed for productive activities such as bracelets, 'maria theresa', necklaces and the like; and are considered to be negatively related to household incomes.
- **credit:** It represents credit taken by households for agricultural activities in the past Meher and Belg seasons. It is supposed to be positively related to household incomes.

5.1.2 Descriptive Statistics of Variables

The sample is taken for 150 households from five selected villages, 30 from each, in the study area. A brief list of mean, standard deviation, minimum and maximum values of each variable is give below:

Table 4: Summary of variables used for Analysis

Variable	Obs	Mean	Std. Dev.	Min	Max
totinc	150	4421.335	3162.897	440	14595
cropinc	150	3805.97	2948.956	60	14595
offinc	150	249.6867	512.6377	0	3650
otherinc	150	365.6787	998.9151	0	8000
areairrig	150	.4210667	.6114853	0	4.25
hhsize	150	4.606667	1.917411	2	12
depratio	150	1.266667	1.082365	0	5
literacyhead	150	.4133333	.4940813	0	1
nuplot	150	3.14	1.528389	1	8
propquality	150	50.97233	26.94967	0	100
propshock	150	17.88853	21.14298	0	83.3
areacultivated	150	1.363467	.97047	.19	8.25
nonlagriassets	150	39.255	22.92533	0	122
selfbusassets	150	121.3333	1387.956	0	17000
nonprodassets	150	407.2453	1540.225	0	18863
credit	150	421.2267	728.8661	0	3000

5.1.3 Multivariate Analysis

In this study, the determinants of income can be analyzed by making income a function of a set of household and village characteristics, including household irrigated area. Hence, our basic model is:

$$y_{hv} = \alpha + \gamma D_{hv} + \mathbf{X_{hv}}\boldsymbol{\beta} + \mathbf{Z_v}\boldsymbol{\delta} + \mu_v + \varepsilon_{hv} \qquad (1)$$[35]

This approach enables us to use village-level data on employment, infrastructure and topography, increases the degrees of freedom and allows us to estimate the importance of these village characteristics. However, it is possible that we have omitted village-level variables that, although unobserved, may affect income and may be correlated with irrigation. One such variable is weather variation in the village. In such a case, we could have an omitted variables problem and estimates of γ would be inconsistent. If this is the case, one solution is to include a set of village dummy variables that capture all of the observed and unobservable village effects. Casting the problem in this way (henceforth, the fixed effects model), however, means that we cannot separate the effect of specific village characteristics (***Zv*** and μ_v) from other village fixed effects since all are captured by the village dummy variables. If we adopt this approach of Huang et al (2005), the fixed effects model that we estimate is:

$$y_{hv} - \bar{y}_{hv} = \gamma\,(D_{hv} - \bar{D}_{hv}) + (\mathrm{X}_{hv} - \bar{\mathrm{X}}_{hv})\,\boldsymbol{\beta} + (\varepsilon_{hv} - \bar{\varepsilon}_{hv}) \qquad (2)$$

where $\bar{y}_{hv}$, $\bar{D}_{hv}$, $\bar{\mathrm{X}}_{hv}$ and $\bar{\varepsilon}_{hv}$ are the averages of variables at the village level.

Based on equation 2 above, the estimate for the sample is given below:

[35] For the description of the variables see section 3.1.1 of Chapter Three.

Table 5: Determinants of Income (Equation 2: Ordinary least squares with fixed effects at the village level)

	Dependent variables (Birr per capita)			
	Total income	Cropping income	Off-farm income	Other income
Area of irrigated land per capita(ha)	2389.763	1854.86	94.58568	440.3165
	(4.06)***	(3.16)***	(0.76)	(1.25)
Household size	640.3573	448.9036	86.39883	105.0549
	(4.10)***	(2.72)***	(2.31)**	(1.92)*
Dependency Ratio of the household	-541.0296	-336.356	-94.46957	-110.204
	(-2.64)***	(-1.73)*	(-1.61)	(-1.13)
Literacy of the household head	70.01131	-8.83016	37.29219	41.54927
	(0.23)	(-0.03)	(0.47)	(0.26)
Degree of land fragmentation (number of plots per household)	116.8751	108.9463	72.22372	-64.29493
	(0.77)	(0.72)	(1.38)	(-0.92)
Proportion of good quality land (%)	5.915985	11.58956	-.9819237	-4.691651
	(0.97)	(1.57)	(-0.52)	(-0.66)
Proportion of output (crops cultivated) affected by negative shocks (%)	-26.36645	-22.669	-1.854707	-1.842743
	(-4.06)***	(-3.83)***	(-1.02)	(-0.75)
Cultivated land per capita (ha)	382.2045	531.1913	-122.7755	-26.21131
	(0.96)	(1.45)	(-1.57)	(-0.19)
Non-land agricultural assets per capita (Birr)	-4.755227	-2.906528	-2.23254	.3838409
	(-0.62)	(-0.39)	(-1.26)	(0.11)
Self-business assets per capita (Birr)	-1.033344	-.3252418	-.4251363	-.2559658
	(-1.50)	(-0.47)	(-2.56)**	(-1.04)
Non-productive assets per capita (Birr)	1.109372	.4480674	.4496623	.2116418
	(1.7)*	(0.70)	(2.77)***	(0.95)
Credit	.155542	.0723494	.0991671	-.0159745
	(0.63)	(0.29)	(0.81)	(-0.11)
Cons.	198.2745	75.72628	142.4539	265.0022
	(0.30)	(0.11)	(-0.77)	(0.57)
R-Square	0.6737	0.6278	0.1244	0.0801

Robust *t*-statistic in parentheses. *Significant at 10 per cent; **significant at 5 per cent; ***significant at 1 per cent.

5.1.4 Regression Results

Our regression estimates of the effect of irrigation on income are shown in Table 5 above. The goodness of fit measure, $R2$, is 0.6737 for total income and 0.6278 for the cropping income equation. These $R2$ are sufficiently high for analyses that use cross-sectional household data. In addition, many of the coefficients associated with the control variables are statistically significant and of the expected sign. For example, dependency ratio negatively affects total income of a household. Also, as expected, negative shocks significantly reduce cropping income.

Most importantly, the results allow us to reject the null hypothesis that irrigated land area has no effect on cropping income and indicate that the descriptive results are largely consistent with multivariate analysis (Table 5, column 2). Increasing irrigated land per capita by one hectare will lead to an increase of 1855 Birr in annual cropping income per capita, holding other household characteristics constant.

Contrary to our expectation, literacy of household head has a negative coefficient against cropping income though not significant. In addition to this, self-business assets per capita, non-land agricultural assets and degree of land fragmentation have a different sign from our expectation but are not significant.

5.2 Irrigation and Poverty

To study more carefully the effects of irrigation on poverty, we use a simulation approach in order to assess the change in poverty incidence arising from a change in a specific factor. To do so, we follow Datt (1998) and Gibson and Rozelle (2003) cited in Q. Huang et al (2005) and use parameters from a regression analysis of the determinants of total income to create a simulation framework. More specifically, the basic model is of (log) income per capita, *yhv*, deflated by the poverty line, *c*, a ratio known as the "welfare ratio".[36]

$$\ln(y_{hv}/c) = \alpha' + \gamma' D_{hv} + X_{hv}\beta' + Z_v\delta' + \mu_v' + \varepsilon_{hv}' \qquad (3)$$

where ε'_{hv} is independently and identically distributed normal random variables with zero means and constant variance, σ_v.

Table 6: Estimates of log welfare ratio for rural households (Ordinary least squares with fixed effects at the village level)

	Dependent variable: Log welfare ratio
Area of irrigated land per capita (ha)	.3908934 (2.73)***
Household size	.0740667 (2.14)**
Dependency Ratio of the household	-.0914834 (-1.45)
Literacy of the head of the household	.0570604 (0.67)
Degree of land fragmentation (no. of plots per household)	.00146827 (0.38)
Proportion of good quality land (%)	-.0009677 (-0.54)
Proportion of output (harvest) affected by negative shocks (%)	-.0098325 (-4.49)***
Cultivated land per capita (ha)	.0926228 (1.04)
Non-land agricultural assets per capita (Birr)	-.0003985 (-0.19)
Non-productive assets per capita (Birr)	-.000049 (-5.46)***
Self-business asset per capita (Birr)	.00000856 (0.71)
Credit	-.00000741 (0.13)
Cons.	2.47706 (13.78)***
R-Square	0.5502

Robust *t*-statistic in parentheses. *Significant at 10 per cent; **significant at 5 per cent; ***significant at 1 per cent.

[36] Blackorby and Donaldson 1984 cited in Q. Huang et al (2005)

5.2.1 Regression Results

The regression of log welfare ratio performs well (Table 6). The magnitude of the coefficients differs between Table 5 and 6 because the dependent variable in Table 6 is a non-linear (log) transformation of that in Table 5. Nonetheless, the signs and statistical significance of the coefficients on most of our key explanatory variables are consistent in both tables (column 1, Table 5; Table 6). In particular, the coefficient on our variable of interest, area of irrigated land per capita, is positive and significant at one percent. However, the sign for the coefficients of credit and proportion of land with good quality is negative contrary to our expectation though it is statistically insignificant.

Normalizing income per capita by the poverty line implies that $\ln\left(y_{hv}/c\right)<0$ for poor households and the probability of the h^{th} household being poor can be derived using the probit model. A weighted average of the household probabilities of being poor gives the predicted incidence of poverty, where the weights are the household sampling weights in terms of household size.

Once the simulation is done, it is possible to look at the effects of increasing irrigated land on poverty reduction. That is, the incidence of poverty may fall/rise by certain percentage points if all non-irrigated land were converted to irrigated land. Thus, the simulation work will clearly show us the effect of irrigation on poverty reduction.

Table 7: Simulated effect of certain changes in area of irrigated land on incidence of poverty in rural Banja Woreda in 2005

	Poverty incidence
Baseline: Actual values	66.65%
Convert households' non-irrigated land into irrigated land	62.20%*** (7.15%) ‡

‡ Percentage change from the predicted baseline values is reported in parenthesis. *** Significant at 1%.

Using the simulation framework, the positive effects of increasing irrigated land on poverty reduction are clear (Table 7). According to the result, the incidence of poverty would fall by 4.45 percent if all non-irrigated land were converted to irrigated land. In percentage terms, poverty line would decline by 7.15 % if all non-irrigated land were converted to irrigated land.

5.3 Computation of Food Poverty Line using the Cost of calories Approach

At this juncture, we can mention several methods of calculating poverty line in Economics such as Food Energy Intake (FEI) method, the Cost of basic needs method and the Food Component method.[37]

However, in this thesis I have preferred to use a method of calculating food poverty line suggested by Joel Greer and Erik Thorbecke, 1986. They proposed a new method, which is conceptually and computationally simple, does not require an excessive sample size, and does not pre-impose a researcher's or bureaucrat's subjective notion of w hat constitutes a palatable, but inexpensive diet. In essence, it requires only two pieces of information for each individual:[38] calorie consumption C_j and food expenditure variable X_j. This latter variable measures both purchased food and the imputed value of food consumption out of own production. Given information on food expenditure and calorie consumption, it is possible to estimate the cost of acquiring a given number of calories by using the cost-of-calories function which, in log linear form, is

$$\ln X = a + bC \qquad (1)$$

[37] For a brief review of methods of calculating poverty lines see section 2.1.3 of chapter 2.

[38] Because expenditure and consumption surveys typically collect data by household, in actual practice j represents households and Cj and Xj are expressed in per adult equivalent terms. This of course requires information on the household's size and composition in order to calculate the number of adult equivalents.

The poverty line Z is the estimated cost of acquiring the calorie RDA, R.[39]

$$Z = e^{(\hat{a}+R\hat{b})}, \qquad (2)$$

where $\hat{a}$ and $\hat{b}$ are the coefficient estimates of a and b, respectively, from equation (1).

Equation (1) approximates an exactly determined but unknown relationship between X and C. It is based on two fundamental assumptions:

(1) All individuals face identical prices; and

(2) There is a common dietary taste pattern.

Based on this calculation, data on consumption expenditure have been collected from five selected rural villages in the study area. The interview is conducted on 150 households and it was found that the food poverty line for the sample is 62.89 Birr per adult per month.

Table 8: Food Calorie Table per 100 gm edible portion Adjusted for Africa

Food Item	Calories per 100gm of edible portion	Food Item	Calories per 100gm of edible portion
Teff-red	3480	Nigerseed-Ethiopian noug whole	4830
Teff-white	3710	Gesho dried	3050
Barley (gebis)	3610	Peppers-Ethiopian food semi dried	2470
Wheat, local	3710	Onion	360
Wheat imported from Europe	3760	Sugar cane	750
Maize-white and pale variety	3570	Tomato-ripe whole	210
Maize/Corn-yellow variety	3640	Tomato-dried	2450
Sorghum-whole grain	3390	Honey, local product	3110
Potato-raw	820	Sugar	3440
Bean-see dried	4260	Beef	1260
Bean-whole seeds	3440	Mutton	2650
Chickpea-whole seeds	3570	Egg	140 per each
Lentil-seeds dried	3450	Ginger	3010
Phaseolus /Adenguare	3340	Alcoholic drinks	6930
Adenguare-black whole seed	3370	Salt	860
Soybean-whole seed	4050	Milk and milk products	7000
		All green plants	3570

(Source: FAO, 1968)

[39] Given information on real total expenditure per adult per month and household calorie consumption we estimated the cost of acquiring 2200 kcal per day per capita using the cost-of-calories function of Greer and Thorbecke (1986). The Recommended Daily Allowance (RDA) we used in this study is proposed by the World Health Organization (WHO, 1985).

5.4 Irrigation and Inequality

To analyze the impact of irrigation on inequality, I have chosen two ways of decomposing inequality:

3. Decomposition by *source of income* (cropping income from irrigated plots, cropping income from non-irrigated plots, off farm income and other income); and
4. Decomposition by estimated *income flows due to specific household characteristics* (e.g., irrigated land area per capita and dependency ratio of the household).

Our methodology is similar in both cases. We first decompose the total income Gini coefficient by income source.

5.4.1 Decomposition by Income Sources

Table 9: Gini decomposition by income sources

Income sources	S_k	G_k	R_k	$S_kG_kR_k$	$\partial G_0/\partial e_j$	$\left(\partial G_0/\partial e_j\right)G_0$
Total income	1	0.393181	1	0.393181		
Cropping income						
From irrigated land	0.891469	0.243251	0.88046	0.1909283	-0.1595804	-0.40587
From non-irrigated land	0.782811	0.450737	0.767015	0.27063526	-0.0371512	-0.09449
Off-farm income	0.056473	0.797757	0.003059	0.00013781	-0.0220664	-0.05612
Other income	0.082708	0.821378	0.071629	0.00486607	-0.0276531	-0.07033

Where, S_k is share of income source k in total income; G_k is Gini coefficient of income source k; R_k is Gini correlation between income source k and the distribution of total income. $S_kG_kR_k$ is contribution of income source k to the Gini coefficient of total income. $\partial Go/\partial e_j$ is marginal effect on the Gini coefficient of total income due to a marginal percentage increase in income source j. $(\partial Go/\partial e_j)G_o$ is relative effect of a marginal percentage increase in income source j upon the Gini coefficient of total income.

The overall Gini coefficient of per capita income from our sample is 0.393 (Table 9, row 1). Decomposing the Gini coefficient by income source shows that irrigation could help to equalize income (Table 9). Cropping income from irrigated land is most equally distributed with a Gini coefficient approximately 0.24 which is very much lower than those of other income sources (Table 9, column 2). More importantly, cropping income from irrigated land has the highest marginal effect on lowering inequality (column 6). A 1 per cent increase in cropping income from irrigated land for all households would decrease the Gini coefficient for total income by 0.41 per cent. Hence, just as Rozelle (1996) cited in Q. Huang et al (2005) found that cropping income, in general, helped abate regional inequality, these results indicate that inter household inequality is significantly reduced by the presence of irrigation.

5.4.2 Decomposition Results by Income Flows

Table 10: Gini decomposition by income flows as a result of specific household characteristics

Income sources	S_k	G_k	R_k	$S_kG_kR_k$	$\partial G_0/\partial e_j$	$\left(\partial G_0/\partial e_j\right)$
Total income per capita (Birr)	1	0.393181	1	0.393181		
Area of irrigated land per capita (ha)	0.22758951	0.675459	0.21132386	0.03248626	-0.0569977	-0.14497
Dependency ratio of the household	-0.154999	0.468725	-0.157835	0.01146701	0.0724097	0.184164
Proportion of good quality land (%)	0.068204	0.292924	0.07335	0.00146543	-0.0253511	-0.06448
Cultivated land per capita (ha)	0.117866	0.329739	0.111892	0.00434868	-0.041994	-0.10681

Where, S_k is share of income source k in total income; G_k is Gini coefficient of income source k; R_k is Gini correlation between income source k and the distribution of total income. $S_kG_kR_k$ is contribution of income source k to the Gini coefficient of total income. $\partial Go/\partial e_j$ is marginal effect on the Gini coefficient of total income due to a marginal percentage increase in income source j. $(\partial Go/\partial e_j)G_o$ is relative effect of a marginal percentage increase in income source j upon the Gini coefficient of total income.

Results from decomposing inequality by income flows as a result of specific household characteristics further confirm irrigation's propensity to equalize income (Table 8). After controlling for other factors, a 1 per cent increase of irrigated land per capita leads to a 0.14 per cent decrease in the Gini coefficient for total income. The results also showed that irrigation is not the only factor that can decrease inequality. A 1 per cent increase in the cultivated land per capita of a household will lead to a 0.11 per cent decrease in the inequality level of total income.

Similarly, proportion of good quality land has also its own contribution in reducing income inequality of households in the study area. On the other hand, dependency ratio has a contrary effect on income inequality. A unit percentage increase in dependency ratio would worsen income distribution by .18 percent.

CHAPTER SIX

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

In this thesis, I have tried to explore the relationship between irrigation status, income, poverty and inequality using a sample of 150 representative households taken from five selected rural villages in Banja woreda-Amhara Region. From the study, our key variable area of irrigated land per capita was found to be positively related to household incomes with statistical significance. In addition to this, variables such as dependency ratio and proportion of output affected by negative shocks were statistically significant and had the expected signs of coefficients. However, most of the rest variables have either unexpected signs, statistically insignificant or are inconsistent in the ordinary least squares with fixed effects model and its semi-log transformation of welfare ratio.

The analysis of this paper does not indicate that investments should be made to increase irrigated area in all villages of the woreda as well as the country as a whole since in some of the villages, costs of increasing irrigation may outweigh benefits of doing so. In addition, returns to investment in irrigation may be lower when other factors are taken into account. One such factor is the negative impacts of irrigation on environment. In other cases, the expansion of irrigated area increases demand for water and may lead to depletion of the groundwater resource that is increasingly scarce. Under such circumstances, investments in irrigation might want to be put into improved irrigation efficiency by providing water saving technologies or improving the performance of irrigation infrastructure. Moreover, irrigation has also a negative side of being a source of malaria infestation in this area of the country. Hence, there should be an increasing concern in health issue with the development of irrigation especially in areas where malaria is prevalent.

To sum-up the above points, using descriptive and multivariate analysis, I found evidence of the strong impact of irrigation on income and poverty. Using alternative decomposition analyses of inequality, I found that irrigation also helps reduce income inequality. Hence, continued investment in new irrigation projects and maintenance of existing systems in Banja will help to attain the government's rural welfare improvement goals. Moreover, as reducing poverty and decreasing inequality both have growth-enhancing effects; irrigation investment could have an added benefit. Irrigation investment in rural Banja Woreda appears to be an investment that can lead to both growth and equity.

6.2 Recommendations and Policy Implications

As commented by Hamdane A. (2002), the overall government policy in any country is to promote social and economic development through irrigated agriculture which is sustainable over time, economically justified, financially viable, socially acceptable and technically sound, without causing unacceptable impacts on the environment. Irrigation development programmes must also benefit as many households as possible and in particular those that belong to the most vulnerable groups of the rural community. Irrigation development, particularly small-scale irrigation, will be an important component of a diversification and expansion strategy to strengthen food security for the future. There is a need to identify crops and irrigation techniques that will give higher returns to irrigation water and overall investment. The best and most economical uses of water for irrigation are essential to any strategy of irrigation development.

Nowadays, we witness a great deal of ventures are already been taken in the area of food security. In relation to the Millennium Development Goals (MDGs), the government of Ethiopia has set its own short and long term plans and strategies to achieve those ends. These endeavours are being stretched from federal to regional, zonal, woreda and kebele levels. Hence, it is the responsibility of every citizen to support these efforts to come to success.

From the finding of this thesis we learn that irrigation has a significantly large contribution to the reduction of poverty incidence in the study area. Other variables such as dependency ratio and proportion of outputs affected by negative shocks were also found to be important concerns to look for the reduction of poverty of households. However, this paper does not have enough information on the cost sides of these factors. Hence, at this point, it is not possible to recommend government to give priorities to one of these variables. Nevertheless, it is important for the people of the woreda to facilitate the development of irrigation projects so as to reduce poverty incidence in the area.

In addition to this, concerned bodies in the area are advised to intensify irrigation schemes as it is found from the study that it has a potentially significant impact in reducing income inequalities among rural residents of the woreda.

The other important implication of the study is that government should enhance the availability of off-farm jobs in the area. This is very crucial for poor rural households to supplement their income so that food security agenda of government would be met.

BIBLIOGRAPHY

- Abbi M. Kedir and Andrew Mc Kay (2003), Chronic Poverty in Urban Ethiopia: Panel Data Evidence, Prepared for International Conference on '*staying poor: Chronic Poverty and Development Policy',* hosted by Institute for Development for Development Policy and Management University of Manchester, UK.
- Abbi Mamo Kedir (1997), Modeling Poverty and its Determinants in Addis Ababa: A Focus on Multinomial Logit Selection Model, Ethiopian Journal of Economics, Volume VI, Number 2, Addis Ababa.
- Almas Heshmati (2005), The Relationship between Income Inequality, Poverty and Globalization, World Institute for Development Economics Research (WIDER), Research Paper NO. 2005/37.
- Anand, S. (1983), *Inequality and Poverty in Malaysia: Measurement and Decomposition*.New York: Oxford University Press.
- Andrew J. Healy and Somchai Jitsuchon (2004), A Spatial Picture of Poverty and Inequality in Thailand: Estmates and a Demonstration, Thailand Development Research Instiute.
- Aniba, B.(2002), Valuation of Wastewater - the Case of Tunisia, Water Demand Management Forum on Water Valuation, 25–27 June 2002, Beirut, Lebanon.
- Arriaga, E. (1984), Measuring and explaining the change in life expectancies, *Demography* 21(1): 83-96.
- Barbier, E.B., Markandya, A. & Pearce, D.W. (1990), Environmental sustainability and cost benefit analysis. *Env. Plan. A*., 22: 1259-1266.

- Benjamin, D., Brandt, L., Glewwe, P., and Guo, L. (2000), Markets, human capital, and inequality: Evidence from rural China, William Davidson Institute Working Papers Series 298, William Davidson Institute at the University of Michigan Business School.
- Bigsten, A., B. Kebede, A. Shimeles and M. Taddesse (2003), Growth and Poverty Reduction in Ethiopia: Evidence from Household Panel Surveys. World Development, Vol. 31 (1): 87 –106.
- Blackorby C. and Donaldson D.(1984), Welfare ratios and Distributionally Sensitive Cost-benefit Analysis, *Journal of Public Economics* 34, 265-290.
- Bruinsma, J. (ed.) (2003), World Agriculture: Towards 2015/2030, An FAO Perspective, Earthscan, London.
- Burgess, Simon and Carol Propper (1998), "An Economic Model of Household Income Dynamics, with an Application to Poverty Dynamics among American Women." *CASE Discussion Paper* No. 9.
- Chichilnisky, Graciela (1977), "Economic Development and Efficiency Criteria in the Satisfaction of Basic Needs". Applied Mathematical Modelling, Vol. 1, September.
- CSA (1994), Ethiopian Population and Houses Census by Ethiopian Central Statistical Authority, Addis Ababa.
- Daly, H. (1995), on Wilfred Beckerman's critique of sustainable development. *Env. Val.,* 4(1): 49-55.
- Datt, G. (1998), Simulating poverty measures from regression models of household consumption, Discussion paper, International Food Policy Research Institute.

- David Ross, E. Richare Shillington and Clarence Lochhead (1994), A working definition of Statistics Canada Low Income Cut-offs (LICOs) from the Canadian Fact Book on Poverty, the Canadian Council on Social Development, Canada.
- Deaton, A. and Muellbauer, J. (2003), Economics and Consumer Behaviour, Cambridge University Press, New York.
- De Moor, A. & Calamai, P. (1997), *Subsidizing unsustainable development - undermining the earth with public funds,* the Earth Council.
- El Yacoubi, Z. and Belghiti, M. (2002), Valuation of Irrigation Water - the Case of Morocco, Water Demand Management Forum on Water Valuation, 25–27 June 2002, Beirut, Lebanon.
- European Commission (1998), *Towards sustainable water resources management: a strategic approach*, Luxembourg.
- Facon, T. (2002), Improving the irrigation service to farmers: a key issue in participatory irrigation management, FAO Regional Office for Asia and the Pacific, Under publication by the Asian Productivity Organization.
- FAO (1968), Food Composition Table for Use in Africa, A research Project Sponsored by US Department of Health, Education, and Welfare; and Food and Agriculture Organizations of the United Nations, Rome, Italy, 1968.
- FAO (1996), Control of water pollution from agriculture, by E.D. Ongley. Irrigation and Drainage Paper No. 55. Rome.
- FAO (2002a), Crops and drops - making the best use of water for agriculture, Rome.
- FAO (2002b), New Partnership for Africa's Development (NEPAD) Comprehensive Africa Agriculture Development Programme, November 2002.
- FAO (2003a), Unlocking the water potential of agriculture. Rome.

- FAO (2003b), Issue paper for Ministerial meeting on water for food and agriculture, Kyoto, Japan.
- FAO (2003c), World agriculture: Towards 2015/2030. London, Earthscan Publications Ltd. Lodon.
- FAO (2004), Water charging in irrigated agriculture: an analysis of internal experience. FAO Water Reports No. 27. Rome.
- FAO (2004), AQUASTAT Web site http://www.fao.org/ag/aquastat.
- Felicia O. Akinyemi (2005), Towards a Spatial Information Model for Poverty Reduction and Management in Sub-Saharan Africa, From Pharaohs to Geoinformatics, FIG Working Week 2005 and GSDI-8; Cairo, Egypt.
- Gibson, J., and Rozelle, S.(2003), Poverty and access to roads in Papua New Guinea, *Economic Development and Cultural Change* 52, 159-185.
- Hamdane, A. (2002), Valuation of Irrigation Water - the Case of Tunisia, Water Demand Management Forum on Water Valuation, 25–27 June 2002, Beirut, Lebanon.
- Hanada, K. (1983), A formula of Gini's concentration ratio and its application to life tables. *Journal of Japan Statistical Society*, 13: 95-98.
- Herrera, Amilcar O., Hugo D. Scolnik (1976), Graciela Chichilnisky et all, *Catastrophe or New Society,* International Development Research Center, Ottawa, Canada.
- *http://www.britannica.com* cited in United States Census Bureau,

  http://www.census.gov/hhes/poverty/poverty00/pov00hi.html.
- IMF (1999), Ethiopia: recent economic developments. Washington, DC.
- International Conference on Water and the Environment (ICWE) (1992), *The Dublin Statement on water and sustainable development*, Geneva, Switzerland, Hydrology and Water Resources Department, World Meteorological Organization.

- International Fund for Agricultural Development (IFAD) (2001), *Rural poverty report 2001 the challenge of ending rural poverty,* Oxford, UK, Oxford University Press.
- Joel Greer and Erik Thorbecke (1986), A Methodology for Measuring Food Poverty Applied to Kenya, Journal of Development Economics 24 (1986) 59-74, North-Holland.
- Joel Greer and Erik Thorbecke (1986), Food Poverty Profile Applied to Kenyan Smallholders, Economic Development and Cultural Change, Vol. 35, No. 1, 115-141.
- Kapteyn, A. P. Kooremand and R. Willmesse (1988), 'Some Methodological Issues in the Implementation of Subjective Poverty Definitions,' Journal of Human Resource 23(2):222-242.
- Kendall, M.G., Stuart, A. (1966), *The Advanced Theory of Statistics*. London: Charles Griffin.
- K.K. Tanji & N.C. Kielen (2002c), Agricultural drainage water management in arid and semi-arid areas, by. Irrigation and Drainage Paper No. 61, FAO, Rome.
- Lahlou, A.A. and Bahaj, D. (2002), Valuation of Drinking Water - the Case of Morocco, Water Demand Management Forum on Water Valuation, 25–27 June 2002, Beirut, Lebanon.
- Lahlou, A.A. and Chigguer, J. (2002), Valuation of Wastewater - the Case of Morocco, Water Demand Management Forum on Water Valuation, 25–27 June 2002, Beirut, Lebanon.
- Lerman, R. I., and Yitzhaki, S. (1985). Income inequality effects by income sources: A new approach and applications to the U.S, *The Review of Economics and Statistics* 67, 151-156.
- Marsh, L.L., Porter, D.R. & Salvesen, D.A.(1996), *Mitigation banking: theory and practice*, Washington, DC, Island Press.

- Mekonnen Tadesse (1999), Determinants and Dynamics of Urban Poverty in Ethiopia, Ethiopian Journal of Economics, Special Issue, volume III, Number 1.
- McCrain, G.R. (1992), Habitat evaluation procedures (HEP) applied to mitigation banking in North Carolina. *J. Env. Man.*, 35: 153-162.
- MOFED(2002), Ethiopia: Sustainable Development and Poverty Reduction Program, Federal Democratic Republic of Ethiopia(FDRE), Ministry of Finance and Economic Development(MOFED), Addis Ababa, Ethiopia.
- Morduch, J., and Sicular, T. (2002), Rethinking inequality decomposition, with evidence from rural China, *The Economic Journal* 112, 93-106.
- Motiur Rahman and S. Huda,(1992), Decomposition of Income Inequality in Rural Bangldesh, Modern Asian Studies, Great Britain.
- Ogwang, T. (2000). 'A Convenient Method of Computing the Gini Index and its Standard Error', *Oxford Bulletin of Economics and Statistics*, Vol. 62, pp. 123-29.
- Paxson, C. H. (1992), Using weather variability to estimate the response of savings to transitory income in Thailand, *American Economic Review* 82, 15-33.
- Pearce, D.W. & Turner, R.K.(1990), *Economics of natural resources and the environment, London*, Harvester Wheatsheaf.
- Pearce, D.W., Markandya, A. & Barbier, E.B. (1989), *Blueprint for a green economy*. London, Earthscan.
- Price, M. (2002), Who needs sustainability? In: Hiscock, K M, Rivett, M O and Davison, R M (eds) 2002, Sustainable groundwater development. Geological Society, London, Special Publications 193: 75-81.

- Pyatt, G. (1976), On the interpretation and disaggregation of Gini coefficients, *The Economic Journal* 86, 243-255.
- Pyatt, G., Chen, C., and Fei, J. (1980), The distribution of income by factor components, *Quarterly Journal of Economics* 95, 451-473.
- Q. Huang, David Dawe, Scott Rozelle, Jikun Huang and Jinxia Wang, (2005), Irrigation, Poverty and Inequality in Rural China, *The Australian Journal of Agricultural and Resource Economics*, 49, 159-175.
- Randolph, Susan, (1982), Measures of absolute poverty and their applications in program Planning and evaluation for increasing participation, Occasional Papers no. 13 (Rural Development Committee, Cornell University, Ithaca, NY.
- Ravallion, M and Bidani, B.(1994), 'How Robust is a Poverty Profile?', World Bank Economic Review, 8(1):75-102.
- Rosegrant, M.W., Cai, X. & Cline, S.A. (2002), *World water and food to 2025: dealing with scarcity*. Washington, DC, International Food Policy Research Institute.
- Saghir, J. (2002), World Bank presentation at the Water Demand Management Forum on Water Valuation, 25–27 June 2002, Beirut, Lebanon.
- Sen, Amartya, (1978), Three notes on the concept of poverty, Research working paper, World Employment Programme, International Labour Office, Geneva.
- Solow Robert M. (1992), *An Almost Practical Step Towards Sustainability*, Invited Lecture on the Occasion of the Fortieth Anniversary of Resources for the Future, Resouces and Conservation Center, Washington, D. C.

- Stephen M.K. Donkor (2004), Development Challenges of Water Resource Management in Africa, African Water Journal, Economic Commission for Africa (ECA), Addis Ababa, Ethiopia.
- Stuart, A. (1954), The correlation between variate-values and ranks in samples from a continuous distribution, *British Journal of Statistical Psychology* 12, 37-44.
- Taha, S. and Bataineh, F. (2002), Valuation of Water for Domestic Use - the Case of Jordan.Water Demand Management Forum on Water Valuation, 25–27 June 2002, Beirut, Lebanon.
- Taylor, J. E. (1997). Remittances and inequality reconsidered: Direct, indirect, and intertemporal effects, *Journal of Policy Modeling* 14, 187-208.
- Turner, R.K. (1993), Sustainable environmental economics and management: principles and practice. London, Belhaven Press.
- UN (1992), *Report of the United Nations Conference on Environment and Development*. Geneva.
- UN (2002), The Johannesburg Declaration on Sustainable Development: World Summit on Sustainable Development, Johannesburg.
- UN (2004), Implementation of the United Nations Millennium Declaration: Report of the Secretary-General, A/59/282 59 Session General Assembly.
- Watts, Harlod W. (1967), The measurement of poverty- an exploratory exercise, American Statistical Association Proceedings of the social Statistics Section, pp. 1-14.
- Wikipedia-free encyclopedia at *http://www.wikipedia.org/*.
- World Bank (2003), *Water resources sector strategy: strategic directions for World Bank engagement.* Washington, DC.

- World Commission on Environment and Development (1998), Our Common Future The Brundtland Report), Oxford University Press.
- Xavier Sala-i-Martin (2002), The Disturbing Rise of Global Income Inequality, NBER Working Paper 8904.