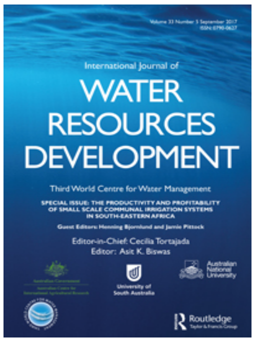

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Income inequality within smallholder irrigation schemes in Sub-Saharan Africa

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ABSTRACT
Equitable income distribution is recognized as critical for poverty reduction, particularly in developing areas. Most of the existing literature is based on region- or country-wide data; fewer empirical studies exist at community levels. This article examines income disparities within six smallholder irrigation schemes in Zimbabwe, Tanzania and Mozambique, comparing inequality at local and national levels, as well as decomposing inequality by group and by source. The results present significant contrasts between schemes and compared to national figures. This evidences that, inadvertently, nation-wide strategies may overlook high inequality at smaller scales, and thus, development policies should be tailored to the specific areas of intervention.

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Introduction

It is estimated that 1.2 billion people across the world live in extreme poverty (UN, 2013). Alongside growth, mitigating socio-economic inequality is widely recognized as a key component of effective poverty-reduction strategies (Groll & Lambert, 2013; Kabubo-Mariara, Mwabu, & Ndeng'e, 2012). In fact, without adequate redistribution interventions, rapid development can lead to excessive economic disparities, often resulting in severe issues such as persistent poverty (Ravallion, 1997), violent crime (Hsieh & Pugh, 1993), corruption (Khagram, 2005), political instability (Alesina, 1996), worsened health (Kawachi & Kennedy, 1997) and low education levels (De Gregorio & Lee, 2002).

The interconnection between growth, poverty and inequality is especially crucial in rural areas, home to 70% of the developing world's extremely poor (Ferreira, 1996; Ortiz & Cummins, 2011; Watkins, 2013). Sub-Saharan Africa (SSA), in particular, suffers from deep and persistent poverty and inequality, which undermine the gains from technological advances, including those in agriculture (Go, Nikitin, Wang, & Zou, 2007). Most of the existing inequality literature is based on national or regional investigations (typically derived from governmental census); fewer studies exist at the level of villages or rural communities, where more detailed data collection is required (Silva, 2013). As a result of this gap, there is a need to further

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understand the poverty–inequality nexus at small scales, in order to define more effective and robust growth strategies (Ostry & Berg, 2011). This question is particularly critical in small-scale irrigation schemes in developing countries, where sustainable irrigation is widely recognized as a powerful tool to mitigate poverty and extreme economic inequality (Chitale, 1994; Makombe & Sampath, 1998).

This study investigates socio-economic inequality in six smallholder irrigation schemes in Zimbabwe, Tanzania and Mozambique. First, income inequality is calculated at a local level and then compared to national figures. Second, income inequality is decomposed by household economic activity – solely agricultural or diversified incomes – to assess the relative importance of the between-group and within-group components. Finally, an analysis by four different income sources determines which components contribute most to total inequality and which ones have an 'equalizing' or 'unequalizing' effect.

Growth, poverty and inequality in Sub-Saharan Africa

Between 1995 and 2013, SSA experienced an average annual GDP growth of 4.5%, accompanied by a 9% drop in the poverty headcount ratio (World Bank, 2014). Nevertheless, the subcontinent is still home to 30% of the word's extremely poor and undernourished population. Following the global trend, income disparity in the region has risen compared to 1980s levels, making SSA the second-most income-unequal subcontinent, after Latin America and the Caribbean (Cogneau et al., 2007). Lesotho, South Africa and Botswana are the most unequal SSA countries, with Gini coefficients above 0.63, while Niger and Ethiopia have the lowest disparities, with Gini coefficients below 0.35 (CIA, 2014).

Zimbabwe ranks among the 10 most unequal SSA countries, with a Gini coefficient of 0.50 in 2006 (CIA, 2014). Such economic disparities are partly derived from its agrarian socio-economic situation, still reflecting the legacy of the colonial era, the civil war and the reforms of the late twentieth century. Throughout the 1980s and 1990s, Zimbabweans' livelihoods deteriorated significantly, as a result of repetitive droughts and issues associated with land reform (Kinsey, 2010; Mazingi & Kamidza, 2011). The national poverty headcount ratio is 72%; in rural areas it is 84% (ZIMSTAT, 2013). Zimbabwe's Human Development Index (HDI) for 2012 was 0.397 – in the 'low' human development category – ranking 172 out of 187 countries and territories (UNDP, 2013).

Tanzania is one of the four most income-equal countries in SSA, with a Gini coefficient of 0.38 in 2007 (CIA, 2014). Its economy is largely dependent on rural activities, with agriculture, hunting and forestry accounting for 27% of GDP, second only to the service sector, at 48% (United Republic of Tanzania, 2013b). In the 1980s and early 1990s, Tanzania experienced significant economic growth, which brought lower poverty but also higher economic inequality (World Bank, 2011). Over the first decade of the 2000s, the average annual GPD grew by 7% and the national HDI rose from 163 to 151 in a world ranking of 189 countries (UNDP, 2011). The poverty headcount ratio across mainland Tanzania is 34%; in rural areas it is 38% (United Republic of Tanzania, 2009).

In Mozambique, income inequality is relatively high, with a 0.46 Gini index, above the SSA median of 0.43 (CIA, 2014). Between 1995 and 2003, agriculture was the second-largest contributor to GDP growth (1.7% out of 8.6%) and the main driver of poverty reduction. Over this period, agriculture experienced an average annual growth of 5.2%, but this mainly represented recovery from the 1977–1992 war, rather than productivity gains from innovation and investment (Virtanen & Ehrenpreis, 2007). In 2008/09, the national poverty headcount ratio was 55%, with rural areas still being more affected (57%) than urban centres (50%) (Arndt, Jones, & Tarp, 2010). Worldwide, Mozambique is the tenth-least developed nation, with an HDI of 0.393 in 2013 (UN, 2014).

Data collection

The countries of study in this article were selected following a scoping exercise covering nine African nations, out of which Zimbabwe, Tanzania and Mozambique were prioritized based on their local expertise, favourable policies and institutions, and potential to increase food production (Pittock, Stirzaker, Sibanda, Sullivan, & Grafton, 2013). In each of the three countries, two irrigation schemes were chosen by local research partner organizations given their institutional capacity, ability to improve agricultural practices, accessibility and the interest of local agencies in collaboration (Rhodes, Bjornlund, & Wheeler, 2014). 'Irrigation scheme' is defined as an area where crops are grown under irrigation through any method (United Republic of Tanzania, 2013a). In this article, 'irrigation scheme' will also be used to refer to an agricultural community whose members own or rent land within the same irrigated area, sharing the same water source and supply infrastructure.

The selected schemes lie within semi-arid climatic areas, where, due to erratic or seasonal rainfall, irrigation is critical to achieve successful crop production (FAO, 2005). Water is abstracted from surface sources and delivered through gravity-fed methods, which is typical of smallholder schemes in semi-arid areas of the three countries. The representativeness of the chosen sites is further discussed in the respective country articles that form part of this special issue.

The six schemes in this study range in size from 10 to 939 hectares, each of them having between 27 and 578 registered member households (Table 1). The average family landholding varies from 0.1 to 1.6 ha, in line with average smallholder landholdings at the respective national levels: 0.12 ha in Zimbabwe (FAO, 2006), 0.9 ha in Tanzania (FAO, 2015) and 1.4 ha in Mozambique (FAO, 2007).

While there is not one consistent definition of 'smallholder farms', the most common approach is to consider them as those with less than 2 ha of cropland (Hazell, Poulton, Wiggins, & Dorward, 2007). Other usual smallholder characteristics (also found in the selected schemes) include low technology, reliance on household members for most of the labour, and dependence on the farm as a principal source of family income (Nagayets, 2005).

Table 1. Characteristics of the irrigation schemes and surveys undertaken.

Country	Irrigation scheme	Total area (ha)	Number of irrigating households	Average household landholding	Surveyed households	Main crops
Zimbabwe	Mkoba	10	75	0.13	68	Maize, horticulture
	Silalabuhwa	110	212	0.52	100	Maize, wheat, sugar beans, vegetables
Tanzania	Kiwere	189	199	0.95	100	Vegetables, maize
	Magozi	939	578	1.62	99	Rice
Mozambique	25 de Setembro	38	38	1.00	25	Vegetables
	Khanimambo	16	27	0.59	9	Vegetables

Source: Rhodes et al. (2014)

Table 2. Revenue and expenditure categories used in household survey.

	Revenue	Expenditure
On-farm	Rainfed crops Irrigated crops Livestock sales Milk sales Other	Crop inputs Harvesting/transport Livestock inputs Hired labour Irrigation Other
Off-farm	Agricultural labour Non-agricultural labour Regular employment Business/self-employment Remittances Seasonal work Other	Food Education Health Social events Housing Personal transport

The schemes in this study are subdivided into farms, each of which is cultivated by one family, with some families having more than one farm. Given the association between farm and household, and not farm and individual, the data-collection process was designed using households as the basic unit. The survey consisted of 65 structured and semi-structured questions, regarding the family members, farm characteristics, food security, asset ownership, revenue and expenses, among other questions.

The surveys were conducted between May and July 2014, with sampling method varying depending on the size of the population. In the three smallest schemes – Mkoba (Zimbabwe), 25 de Setembro and Khanimambo (Mozambique) – the aim was to interview the whole population (though some farmers asked to be excused and others were absent). In the three largest schemes – Silalabuhwa (Zimbabwe), Kiwere and Magozi (Tanzania) – the population was sampled using a stratified approach. Irrigators were categorized according to the gender of the household head and wealth category (poor, medium or well-resourced) and then randomly sampled (Moyo, Moyo, & van Rooyen, 2014).

Data used in this study include household revenues and expenditure over the 12-month period prior to the interview. The information was collected according to source of revenue and type of expenditure, and was then aggregated into on-farm and off-farm categories (Table 2).

Analytical framework

Defining inequality

Economic inequality can be defined in many ways, but it is typically considered to be the uneven distribution of wealth, income and/or assets among individuals of a group, or between groups of individuals (McKay, 2002). While there is not one ideal measurement, the preferred indicators of poverty and living standards tend to be money metrics, i.e. income or consumption expenditure (Sahn & Stifel, 2003). Alternative non-monetary measures exist, such as those based on asset ownership (Filmer & Pritchett, 2001; McKenzie, 2005) and the Multidimensional Poverty Index, combining education, health and living standards indicators (Alkire & Santos, 2011; Kovacevic & Calderon, 2014). In this article, monetary indicators were used so as to compare local and national inequality and to investigate how various income sources contribute to total inequality. Out of a wide range of inequality measures, the section below presents a summary of the two selected indicators.

Gini coefficient

The Gini coefficient measures the extent to which the distribution of wealth within a group deviates from a perfectly equal distribution, with values from 0 to 1 (World Bank, 2011). Its advantages include being commonly used and relatively easy to calculate, having a visual representation, and allowing comparison between populations of different sizes.

The Gini coefficient can be estimated based on the representation of the Lorenz curve, plotting cumulative income vs. cumulative population. It can also be mathematically calculated as:

$$G = cov(y, F(y))\frac{2}{\bar{y}} \tag{1}$$

where cov is the covariance between income levels y and the cumulative distribution of the same income $F(y)$, and $\bar{y}$ is average income.

Lerman and Yitzhaki (1985) developed a method to decompose the Gini coefficient as the sum of the inequality contributions of all income sources:

$$G = \sum_{k=1}^{k} R_k G_k S_k \tag{2}$$

where S_k is the share of income source k in total income, G_k is the Gini coefficient of income source k and R_k is the Gini correlation of income from source k with the distribution of total income. By calculating partial derivatives of the Gini coefficient with respect to a percentage change e in income source k, it is possible to estimate the percentage change in total inequality resulting from a small percentage change in income source k:

$$\frac{\partial G/\partial e}{G} = \frac{R_k G_k S_k}{G} - S_k \tag{3}$$

This property is particularly useful in this study because it allows identification of the 'equalizing' or 'unequalizing' effect of each income source on total inequality (López-Feldman, 2006).

The Gini coefficient also has several restrictions. First, it does not satisfy the properties of aggregativity and additive decomposability (Bourguignon, 1979), limiting its ability to analyze inequality *between* and *within* population subgroups. Moreover, in the presence of negative incomes, the Gini coefficient presents abnormal behaviours, as detailed in the section 'Negative Incomes and Measures of Inequality'.

Theil index

The Theil is a specific case of the generalized entropy indices (Bellù & Liberati, 2006). Its lower value is zero (perfect equality), and it has no upper limit. The index is defined as:

$$T = \frac{1}{n}\Sigma_i\left(\frac{y_i}{\bar{y}}\right)\ln\left(\frac{y_i}{\bar{y}}\right) \tag{4}$$

where y_i is the ith observation and $\bar{y}$ is the average income.

One of its key advantages is being decomposable and additive into groups, thus allowing distinction of *between* and *within* sub-group inequality components. Assuming m groups, the Theil index is decomposed as:

$$T = \Sigma_{k=1}^{m}\left(\frac{n_k}{n}\frac{\bar{y}_k}{\bar{y}}\right)T_k + \Sigma_{k=1}^{m}\frac{n_k}{n}\left(\frac{\bar{y}_k}{\bar{y}}\right)\ln\left(\frac{\bar{y}_k}{\bar{y}}\right) \quad (5)$$

where the first and second terms are the *within-group* and *between-group* components, respectively. Similarly, the Theil index can also be decomposed by source of income, following the expression for m sources:

$$T = \Sigma_{k=1}^{m}\frac{1}{n}\Sigma_{i=1}^{n}\left(\frac{y_i^k}{\bar{y}}\right)\ln\left(\frac{y_i}{\bar{y}}\right) \quad (6)$$

In this study, the decomposition of the Theil index in *between/within sub-groups* and *by income source* was calculated by computing equations (5) and (6).

The Theil index has also some drawbacks, such as not having an intuitive representation and not being suitable for comparing populations of different sizes. Also, it does not support non-positive values, as $\ln(x)$ is undefined for $x \leq 0$. As explained by Bellù and Liberati (2006) and Vasilescu, Serebrenik, and van den Brand (2011), the limitation of zero values can be overcome by replacing zeros with very small values $\varepsilon > 0$, such that $I_{\text{Theil}}(x_1, \ldots, x_{n-1}, 0) \equiv I_{\text{Theil}}(x_1, \ldots, x_{n-1}, \varepsilon)$. In this article, ε is taken as equal to 10^{-10}.

Negative incomes and measures of inequality

Two common measures of agricultural income are net cash income and net farm income. The former is a measure of cash flow representing the money available for debt repayment, investment or withdrawal (Statistics Canada, 2000), while the latter is the value of farm production, including cash and non-cash transactions (Edwards, 2013). Net farm income could not be used in this article because there were no records of non-monetary income transactions, e.g. depreciation, in-kind income or commodities stored. Therefore, net cash income was chosen as the measure of household income from farm sources.

Across the six irrigation schemes, 30% of the households reported higher on-farm expenses than on-farm revenues, resulting in negative net cash income from farming activities. Negative incomes pose a major constraint in the study of inequality, which has been discussed in the literature, with different authors adopting different approaches.

Walker and Ryan (1990) and Möllers and Buchenrieder (2011) note the existence of negative incomes in their data, yet do not discuss the implications or treatment methods for inequality calculation. Schutz (1951) and Stich (1996) indicate that negative incomes are usually excluded from the measurements of income inequality, a method that has been adopted by Cowell (2008), Cribb, Hood, Joyce, and Phillips (2013) and Sanmartin et al. (2003).

Nonetheless, disregarding households with negative net cash incomes is not ideal in this study as it would ignore almost one-third of the sample. Furthermore, this approach is undesirable for agricultural redistribution policies given that it is normal for farms to record losses (Allanson, 2005), and thus it misses out on a key feature of household incomes (Rawal, Swaminathan, & Dhar, 2008).

It is possible to calculate the Gini coefficient including zero and negative values, yet the resulting 'modified' coefficient violates several of its basic properties. First, the principle of transfers (Dalton, 1920), by which a transfer of income from a richer individual to a poorer one leads to a reduction in income inequality, is not always satisfied when the Gini coefficient includes negative incomes. Moreover, the 'modified' Gini coefficient is no longer bounded between 0 and 1, making it inaccurate as a comparison across populations or time. To correct this issue, Chen, Tsaur, and Rhai (1982) proposed a reformulation, referred to as 'normalization', which was subsequently refined by Berrebi and Silber (1985). However, as evidenced by Raffinetti, Siletti, and Vernizzi (2014), this 'normalized Gini' presents abnormal behaviours, such as providing the same inequality measure for two populations having completely different income distributions (total equality and total inequality). Furthermore, it does not allow accurate decomposition by income source (Mishra, El-Osta, & Gillespie, 2009).

The Australian Bureau of Statistics (ABS, 2006) argues that negative incomes often reflect the households' business and investment arrangements or may be a result of accidental or deliberate under-reporting. Therefore, it is inappropriate for them to have a disproportionate influence on inequality measures. Following this argument, the 'equivalization' method is proposed, in which individual income components with negative values are set to zero before computing the total income of each household (OECD, 2014). The process of equivalization has been defined by the OECD and is used by government agencies such as the Australian Bureau of Statistics and the UK Department for Work & Pensions (2014). This technique of truncating the data to report negative incomes as zeros has been applied by Seidl, Pogorelskiy, and Traub (2012) and Bray (2014), who showed consistency of results using various ways of treating negative incomes.

When it comes to adopting one method or another, Smeeding, O'Higgins, and Rainwater (1990) state that each researcher is left to deal with zero and negative incomes as he or she sees fit. Similarly, Deaton (1997) notes that the choice of inequality measures can be made based on practical convenience or on theoretical preference.

Given the interest in maintaining all households in the sample and in using the Gini and Theil indices, the author deemed equivalization the most suitable approach to deal with negative incomes. Thus, negative farm incomes were converted to zero, before being added to other income components to obtain the total. To test the adequacy of the chosen method, a sensitivity analysis was conducted, as described in the appendix.

Results and discussion

Income inequality at scheme and national levels

This section describes the levels of economic inequality within six smallholder agricultural communities and compares them to their respective national figures. Household consumption expenditure and income were used at the scheme level, while family income served as the national indicator, given the available country statistics (Table 3).

Inequalities measured by expenditure are smaller than by income, which is common given that consumption expenditure tends to be more evenly distributed than income (Aguiar & Bils, 2011; Finn, Leibbrandt, & Woolard, 2009; Krueger & Perri, 2006). Income inequalities at the scheme level are generally higher than at national levels. The greatest difference is

Table 3. Inequality at scheme and national levels.

		Scheme level		National level
Country	Scheme	Consumption expenditure Gini	Income Gini	Income Gini
Zimbabwe	Mkoba	0.54	0.60	0.50
	Silalabuhwa	0.47	0.48	0.50
Tanzania	Kiwere	0.54	0.60	0.38
	Magozi	0.39	0.56	0.38
Mozambique	25 de Setembro	0.59	0.65	0.46
	Khanimambo	0.55	0.58	0.46

Source: author's computations for scheme level; CIA (2014) for national levels.

in Tanzania, where Gini income coefficients within the agricultural communities are on the order of 50–60% higher than at the national scale.

The Tanzanian Ministry of Finance and Economic Affairs (United Republic of Tanzania, 2009) argues that, given the country's relatively low levels of inequality, income redistribution is not likely to be effective in achieving significant poverty reduction. Instead, it suggests that continued high rates of economic growth over the long term will be required. In contrast, this study finds that significant income inequalities exist at smaller scales, which are currently being overlooked by country-wide statistics.

Income dualism between agricultural and diversified sources

In rural developing areas, non-agricultural earnings represent an important part of households' incomes, but they can also create significant economic inequalities (Barrett, Reardon, & Webb, 2001; Escobal, 2001; Reardon, 1997). Hence, the aim of this section is to analyze income differences *between* and *within* two groups of households: (1) those earning incomes exclusively from agriculture (including farm income and agricultural labour); and (2) those with diversified incomes (including non-agricultural labour, regular, seasonal or self-employment, business, remittances and other).

Non-parametric tests of statistical significance, Wilcoxon rank-sum (WRS) and Kolmogorov-Smirnov (KS), were used to analyze differences in the distribution of incomes between population subgroups. Common parametric tests could not be used because they require making assumptions on parameters characterizing the populations' distributions, which was not possible given the data available for this study.

In Zimbabwe, the vast majority of households have diversified incomes, while in Tanzania and Mozambique, only half obtain earnings outside of agriculture (Table 4). One common characteristic of all six communities is that households making a living exclusively from agriculture had consistently lower mean and median incomes than those with diversified incomes. The WRS and the KS tests indicated that the distribution of income is not the same in both groups and that exclusively agricultural households rank lower in the overall income distribution. The WRS test ($p < .1$) indicated that the null hypothesis that incomes of agricultural households are not different from diversified-income households could be rejected. Similarly, the KS test concluded that ($p < .1$) the hypothesis that both groups have the same distribution was also rejected in all schemes, except for Magozi.

Despite the remarkable contrast *between* agricultural and diversified income households, the Theil index decomposition reveals that disparities *within* these two groups are actually the main contributor to overall inequality (Table 5). The only exception is Khanimambo,

Table 4. Income statistics by type of income.

Scheme	*n*		Mean household income*		Median household income*		Wilcoxon rank-sum test		Kolmogorov-Smirnov test	
	Ag.	Div.	Ag.	Div.	Ag.	Div.	*Z*	*p*	*D*	*p*
Mkoba	6	62	179	1,098	67	475	−2.52	0.012	0.66	0.009
Silalabuhwa	20	80	411	940	180	700	−3.55	0.000	0.48	0.001
Kiwere	56	44	1,006	2,026	436	1,203	−3.29	0.001	0.43	0.000
Magozi	48	51	1,500	2,905	1,007	1,458	−1.79	0.074	0.20	0.217
25 de Setembro	14	11	40,634	187,707	27,930	84,000	−2.63	0.009	0.55	0.030
Khanimambo	4	5	5,250	177,610	0	173,200	−2.49	0.013	1.00	0.016

*Mkoba, Silalabuhwa in USD; Kiwere, Magozi in TZS 1000; 25 de Setembro, Khanimambo in MZN.
Ag.: exclusively agricultural-income household; Div.: diversified-income household.

Table 5. Household income analysis and decomposition by activity group.

Scheme	Percentage of ag. households	Gini		Theil	
		Ag.	Div.	Within	Between
Mkoba	9%	0.59	0.58	92%	8%
Silalabuhwa	20%	0.49	0.45	91%	9%
Kiwere	56%	0.59	0.69	90%	10%
Magozi	48%	0.55	0.59	92%	8%
25 de Setembro	56%	0.64	0.43	72%	28%
Khanimambo	44%	0.56	0.54	27%	73%

Ag.: exclusively agricultural-income household; Div.: diversified-income household.

yet results from small samples should be interpreted with caution, given the low power of statistical tests (see the Limitations section).

These results conclude that households with diversified earnings have higher incomes than those exclusively dedicated to agriculture, which is consistent with findings elsewhere in Africa (Barrett et al., 2001). As a result of barriers to entry, poor households typically struggle to access highly profitable non-farming activities, whereas more advantaged families tend to profit from greater returns, thus creating a negative feedback loop between poverty, inequality and diversification (Barrett, Bezuneh, & Aboud, 2001; Woldenhanna & Oskam, 2001). Furthermore, the findings in this section contribute to the existing literature by showing that the contrast *between* diversified and non-diversified income households only explains a minor portion of overall income inequality; disparities *within* each group are in fact the major driver.

Relative importance of income sources in total inequality

An extensive literature review by Senadza (2011) concluded that, to better understand the effects of income on inequality, it is important to distinguish between the various components of non-farm income. Hence, this section analyzes the effect on total inequality derived from four distinct income sources: *agricultural*, including on-farm income and agricultural labour; *wages*, including non-agricultural labour, regular employment and seasonal work; *business and self-employment*; and *other*, including remittances and other unspecified sources.

Table 6. Income and inequality decomposition by source.

Scheme	Agriculture		Wages		Business and self-employment		Other	
	Share of income	Share of inequality	Share of income	Share of inequality	Share of income	Share of inequality	Share of income	Share of inequality
Mkoba	19%	2%	15%	23%	14%	17%	52%	58%
Silalabuhwa	34%	14%	17%	42%	5%	3%	44%	42%
Kiwere	79%	83%	7%	6%	11%	9%	3%	1%
Magozi	66%	43%	9%	15%	23%	42%	2%	0%
25 de Setembro	46%	10%	47%	86%	6%	4%	1%	0%
Khanimambo	52%	48%	43%	47%	5%	5%	0%	0%

Table 7. Gini decomposition by income source and marginal effects.

Scheme	Agriculture		Wages		Business and self-employment		Other	
	Gini	% change	Gini	% change	Gini	% change	Gini	% change
Mkoba	0.76	−0.07***	0.93	0.02	0.92	0.02	0.76	0.04
Silalabuhwa	0.68	−0.07**	0.94	0.10**	0.91	−0.01	0.70	−0.01
Kiwere	0.66	0.01	0.94	0.00	0.92	−0.01	0.92	−0.01
Magozi	0.57	−0.09**	0.95	0.02	0.91	0.08*	0.96	−0.01*
25 de Setembro	0.54	−0.13***	0.90	0.13**	0.91	0.01	0.90	−0.01***
Khanimambo	0.61	−0.06	0.69	0.06	0.75	−0.01	N/A	N/A

***$p < .01$; **$p < .05$; *$p < .1$.

In Tanzania, agriculture is the most important source of income, accounting for three-quarters of total earnings and ca. 80% of inequality (Table 6). In contrast, Zimbabwean schemes rely more heavily on other sources (between half and two-thirds comes from remittances), which also account for the largest portion of total income disparities. In Mozambique, incomes and inequalities are mainly split between agriculture and wages.

A key rationale for understanding inequality and formulating policies is to investigate how changes in a particular income source affect overall inequality (Shariff & Azam, 2009; Singh & Dey, 2010). In order to answer this question, a Gini decomposition following equations (2) and (3) was carried out. For each income source, the results summarized in Table 7 indicate the marginal impact in total inequality due to a 1% increase in that particular source, holding all other sources constant. The direction and magnitude of the marginal impact are given by the *% change*. A negative sign indicates a tendency to reduce total inequality, while a positive sign reveals an unequalizing effect. To test the statistical significance of the marginal impacts, 99%, 95% and 90% confidence intervals were calculated using bootstrapping techniques.

In four of the six schemes (Mkoba, Silalabuhwa, Magozi and 25 Setembro), agriculture has an equalizing effect that is statistically significant. Conversely, wage incomes have an unequalizing effect across the six schemes, although only two schemes (Silalabuhwa and 25 de Setembro) showed statistical significance. Little can be said about the effect of business and self-employment, as the marginal impacts are mixed across the various schemes and only statistically significant in Magozi. 'Other' income has mainly an equalizing effect, with statistical significance in Magozi and 25 de Setembro.

A literature review undertaken by Lay, Mahmoud, and M'Mukaria (2008) on the equalizing or unequalizing effect of non-agricultural incomes concluded that the results of various studies were mixed and seemingly contradictory. These inconsistencies, similar to the ones found in this study, could be reconciled by further investigating the underlying drivers of inequality that are specific to each income source.

Limitations

This study has three major limitations. First, the populations of study consist only of members of irrigation schemes, not the entire rural communities, comprising also dryland farmers and non-farmers. This is because the data for this study were collected as part of a research project focused on irrigated agriculture (ACIAR, 2013). Studying the entire community would not have been possible since there is no comprehensive list of all its members that would allow adequate probability sampling. On the other hand, irrigation organizations have up-to-date lists of all their members. If more data become available, future research could be extended to examine differences in income and inequality within the entire rural communities, particularly comparing irrigators and non-irrigators, as well as farmers and non-farmers.

The second limitation is the large proportion of households reporting negative net cash incomes from farming activities. It is possible that farm earnings were under-reported and expenses over-reported, either accidentally or deliberately. Therefore, an improvement could have been made by identifying negative farm incomes during the interviews to then question participants about their financial losses. This would have improved the accuracy of the records and provided greater insight into why certain households experience negative incomes.

The third limitation is the small population samples in Mozambique ($n < 30$), which undermines the robustness of statistical significance tests and can result in underestimation of the Gini coefficient (Deltas, 2003). This problem was partially addressed by using non-parametric tests, which are preferred for small samples (Vickers, 2005). An alternative would have been to remove Mozambique from the study, but it was the author's choice to use the six irrigation schemes, as this article will form part of a special issue dedicated to the three countries: Zimbabwe, Tanzania and Mozambique. Moreover, despite their small size, the 25 de Setembro and Khanimambo schemes can still be considered representative examples of small-scale irrigation in Mozambique, as explained in the Data Collection section.

Conclusions

This article analyzed income inequality within six smallholder irrigation schemes in Zimbabwe, Tanzania and Mozambique using household survey data from 2014. The Gini and Theil indices were used to measure income inequality and decompose inequalities by activity sector and source.

The results indicate that income inequality within the irrigation communities is considerably higher (20–60%) than their respective country-wide figures. Moreover, across the six schemes, exclusively agricultural households earn consistently lower incomes than those with diversified incomes. In Tanzania, the largest source of income and inequality is agriculture, while in Zimbabwe 'other' sources are predominant. In four of the six schemes, agriculture has an equalizing effect, whereas non-agricultural incomes had mixed effects that generally lack statistical significance.

These findings have important policy implications. First, it is crucial to recognize the existence of high levels of income inequality at small scales. Therefore, widespread strategies should be carefully examined before being applied within local contexts, as they could overlook existing disparities and thus perpetuate, or even worsen, economic inequality. Policies incorporating income distribution considerations at local scales would be more effective in achieving poverty reduction, rather than those targeting only broad-based economic growth.

Second, strategies aiming to reduce inequality within smallholder irrigation schemes should be twofold. On the one hand, removal of barriers to entry and diversification into more gainful, non-farm activates could help lift the income of poor, exclusively agricultural households. On the other hand, it is also crucial to address inequality *within* activity groups. A suggested approach would be to target development efforts to those households that are most severely affected by poverty within each activity group.

Finally, because agriculture tends to have an equalizing effect, increasing farming productivity could also contribute to reducing income inequality in some cases. However, it is crucial to bear in mind that results from a certain community should not be generalized to larger extents without the appropriate evidence. In fact, the same strategy targeting growth in a certain activity sector could have a positive, equalizing effect in some communities, and the exact opposite (unequalizing) in others.

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Appendix: Sensitivity analysis

This appendix provides the results of a sensitivity analysis using various methods of estimating income inequality to verify consistency of results.

The five columns in Table A1 summarize income Gini coefficients calculated based on five different methods: (1) converting negative farm incomes to zero; (2) excluding households with negative farm income; (3) excluding households with negative household income; (4) using household earnings, without expenses; and (5) no data treatment (i.e. total household revenue minus total farm expenses).

Excluding households with negative incomes (Columns 2 and 3) tends to underestimate income inequality, as the bottom part of the distribution is not taken into account. The exception is the Khanimambo scheme, where there are no households with negative incomes. Using only revenue (Column 4) also provides lower values, indicating that gross revenue is more evenly distributed than net income. Finally, 'modified' Gini coefficients including negative incomes (Column 5) cannot be used for comparison because they are not bounded by a common scale (0–1). The differences across the various methods are generally consistent with those found previously in the literature (Bray, 2014).

Table A2 summarizes the marginal effects of each source of income using two alternative methods for treating negative figures: excluding housholds with negative farm incomes; and considering revenues only. In these cases, growth in agricultural income tends to reduce inequality, consistently with the results provided in the core of this study. When excluding negative farm incomes, business and self-employment income appears to have an unequalizing effect in four of the six schemes.

Other treatment methods that do not eliminate negative farm incomes (i.e. exclusion of negative household incomes and no data treatment) cannot be used in marginal impact analysis, given the comparison restrictions of the 'modified' Gini coefficient.

Table A3 summarizes the results of the Theil index sensitivity analysis. Theil indices calculated based on earnings (Column 4) are lower than those based on net income, as in the case of the Gini coefficients. Calculations excluding households with negative and zero incomes (Columns 2 and 3) do not allow direct comparisons with other methods because of the different population sizes.

Table A1. Gini coefficient sensitivity analysis

	Income Gini adjusted for negative farm incomes	Income Gini excluding HHs with negative farm income	Income Gini excluding HHs with negative HH income	Gini for HH revenue, not considering farm expenses	Income Gini including negative incomes
Mkoba	0.60	0.51	0.58	0.57	0.63
Silalabuhwa	0.48	0.44	0.46	0.42	0.52
Kiwere	0.60	0.52	0.52	0.53	0.93
Magozi	0.56	0.55	0.55	0.51	0.66
25 de Setembro	0.65	0.62	0.62	0.64	0.85
Khanimambo	0.58	0.55	0.59	0.57	0.59

Table A2. Gini coefficient decomposition sensitivity analysis (percentage change by method of calculation).

	Excluding households with negative farm income				Revenue only (not considering farm expenses)			
	Ag.	Sal./wages	BSE	Other	Ag.	Sal./wages	BSE	Other
Mkoba	−0.03***	0.01	0.02**	0.00	−0.10***	0.02	0.02	0.05*
Silalabuhwa	−0.03**	0.01	0.02*	0.00**	−0.10*	0.10	0.01	0.00
Kiwere	0.03	−0.01	−0.01	−0.01***	−0.01	0.01	0.00	0.00
Magozi	0.00	0.00	0.01	−0.01	−0.09**	0.02	0.07***	0.00
25 de Setembro	−0.03***	0.01	0.03**	0.00	−0.10	0.11*	0.00	0.00***
Khanimambo	−0.03***	0.01	0.03**		−0.03	0.04	−0.01	

Notes: ***$p < .01$; **$p < .05$; *$p < .1$. BSE = business and self-employment.

Table A3. Theil index sensitivity analysis.

	Income Theil adjusted for negative farm incomes	Income Theil excluding HHs with negative and zero farm income	Income Theil excluding HHs with negative and zero HH income	Theil for HH revenue (not considering farm expenses)
Mkoba	0.64	0.45	0.58	0.55
Silalabuhwa	0.41	0.31	0.35	0.27
Kiwere	0.63	0.47	0.46	0.46
Magozi	0.60	0.56	0.58	0.46
25 de Setembro	0.89	0.73	0.74	0.66
Khanimambo	0.66	0.17	0.31	0.36