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Plot Size Constraints and Functionality Perceptions in Smallholder Irrigation Schemes: Evidence from Masvingo Province, Zimbabwe

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Abstract

Despite the substantial investments made towards smallholder irrigation schemes in Sub-Saharan Africa, there is an observable difference between the expectations and reality, without any knowledge of how the farmers perceive functionality and the gap that exists between development objectives and farmers' needs. The research focuses on identifying the needs, perception of benefits, and utility attributes of irrigation schemes to smallholder farmers in the Masvingo Province of Zimbabwe, with emphasis on limitations posed by plot sizes and their influence on income generation and scheme sustainability. Utilising principles of the pragmatist research philosophy and ethnographic methods, data were collected from 181 randomly selected farmers across 14 irrigation schemes in Masvingo Province via semi-structured interviews and focus group discussions. Cronbach's alpha coefficients were computed to check the internal consistency (α = 0.791), and multiple regression analysis was employed to examine the relationship between plot size and income earnings. Thematic analysis was done to find out how farmers view irrigation scheme functionality. Farmers mainly had 0.5ha plots, combining both mixed crop production and household consumption. 81% of farmers considered schemes operational when the water reached their plots, while only 57% considered that more than 50% of the provincial irrigation area functioned, due to varied stakeholder definitions of what constitutes functionality. Multiple regression had detected a significant positive correlation ($p<0.001$, $R^2=0.596$) between plot size and income earnings. Farmers with plots of <1ha gained ≤USD1,300 annually, for the most part, to meet food needs. The two key elements needed for maximum income generation (USD2,500-3,500) and scheme sustainability were plot sizes of 2.3-2.6ha, allowing farmers to transition from subsistence-level livelihood to productive commercial activity. At present, the allocation of only 0.5ha plots restricts income generation and propels the cycle of 'build-neglect-rehabilitate-neglect' in Zimbabwe's smallholder irrigation schemes. Reform on the policy landscape that increases minimum plot sizes to 2.4-2.6ha and governance frameworks that support a broad spectrum of support programs from extension to market access and financial products will be important to transition irrigation schemes from subsistence to viable business ventures. Such reforms entail political courage and a commitment to compensatory aid for excluded farmers, as they represent the sole enduring route for irrigation schemes to become a real driver of rural development and ultimately address poverty concerns.

Keywords: Smallholder irrigation: Plot size optimization: Irrigation functionality: Water productivity: Rural livelihoods: Income generation: Zimbabwe: Sub-Saharan Africa.

Introduction

The Zimbabwean government has identified irrigation development as a vital intervention and key accelerator to guarantee food security, improve incomes, and uplift the economic status of rural communities while providing the much-needed raw materials for industrial development in pursuit of Vision 2030. Over the past four decades, substantial funds have been invested in complementary infrastructure development, with government and donor partners financing various programmes aimed at rehabilitation and development of new irrigation schemes. Despite this massive support, irrigation construction projects have failed to meet overall expectations of stakeholders due to a myriad of reasons: a fragile macro-economic environment, climate change, poor transport networks, incompetent markets, and weak institutional and policy frameworks. Analysis of past programme interventions by Chitsungo and Yangalio (2023) has exposed glaring duplication of effort and resources on several irrigation schemes in Zimbabwe's Masvingo Province, projecting a vicious cycle of 'build, neglect, rehabilitate, neglect' as put forward by Araral (2005). This implies unsustainable and failed investment or development models. Food production is inextricably entwined with the availability of water for agricultural use, and irrigation-based farming is more reliable in general than dryland agriculture (Xie et al., 2018). Increased revenue and food security for poor farmers in Sub-Saharan Africa (SSA) are believed to be attainable through the adoption of smallholder irrigation (Burney and Naylor, 2012).

Nearly all Sub-Saharan African governments have come to an agreement that increasing the area under irrigation must be implemented as part of climate-proofing agriculture, which is also an ingredient of food security in the region. According to Scheumann et al. (2017), water infrastructure investments are not sufficient for SSA countries; development of irrigation should be considered under a broader umbrella support scheme, which will bring farmers secure power supply, extension, financing instruments, input supply, but especially access to competent markets. Smallholder irrigation schemes in Zimbabwe, therefore, represent a good candidate to help boost the rural economy as well as food security and reduce poverty. Yet persistent flaws in government policies, management systems and economies have seriously retarded this project's success. It is now clear that management quality, farmer training, and stakeholder participation are more important than scale and ownership for the success of these schemes. Consequently, through the development of a national irrigation policy as well as a participatory management framework, such schemes will have to be fully realized (Alqaisi, 2018; Moyo et al., 2017; Pittock et al., 2020). Therefore, the problem statement reveals a policy vacuum resulting in confusion over management as well as costs and benefits without a national irrigation policy. Rukuni et al. (2006) stress that successful government-led irrigation schemes are often compromised by poor farmer management and top-down management. In addition, ambiguous ownership of land tenure by the government leads to a scarcity of collateral ownership by farmers, resulting in a shared infrastructure that does not reflect accountability (Moyo et al., 2017). There are also economic limitations, which appear to indicate that the small plot size between 0.2 and 0.5 hectares and insecure tenure hinder investment and profitability, as pointed out by Mupawose and Blackie (1984). Consequently, farmers can earn low yields and are unable to cover their operation and maintenance costs due to low productivity. Main findings based on the research include that stakeholder participation is crucial, as participation of the local community enhances the sustainability and accountability of irrigation schemes. The training of farmers is important for better water utilization and improved productivity, as has been suggested by Yokwe (2009). Quality of management is recognized to be more important than the size of the schemes and/or ownership (Alqaisi, 2018).

Comparing results also show that although several African irrigation schemes fail because of poor institutions and poor tenure, those in Asia have higher success rates because of better community management and feasible plot sizes (Pittock et al., 2020). These issues are considered in several proposals. For one, a national irrigation policy would be clarifying in terms of roles and responsibilities, even ownership, aligning national and local governance structures. Facilitating participatory methods will also be indispensable, as when farmers, local leaders and communities are engaged in planning and execution, it creates increased ownership and accountability. Through this training in irrigation techniques, water management and agribusiness, farmer capability would be built so that farmers can be able to gain maximum productivity.

Another pertinent recommendation is to reform land tenure and plot sizes. Through land tenure reforms, it will encourage investment and production of more commodities, while the consolidation of land will lead to economies of scale. In addition, sustainable financing arrangements must be put in place so that farmers can borrow and arrange cost-sharing mechanisms for the operation and maintenance of irrigation schemes. Finally, there should be a focus on conducting research to learn from successful models in Asia that can be applied in Zimbabwe. Smallholder irrigation schemes could constitute a pillar of rural development in Zimbabwe. Success is contingent on the execution of a sound national policy, participative models of governance, farmer training, secure land tenure, and sustainable financing. Without these basic reforms, irrigation schemes might remain economically unfeasible and socially unviable.

Although the performance of irrigation schemes has been widely explored in the literature, there is limited research investigating the disconnect between farmer perceptions of functionality and development objectives, particularly regarding the optimal allocation of plot size in relation to policy. Farmers have varying needs for the establishment or rehabilitation of irrigation schemes, and understanding their needs, the benefits they derive from irrigation schemes, as well as their perceptions of the system's functionality, provides insights related to farmers' perceptions of irrigation scheme functionality from the perspective of policymakers. Thus, this research aims at enabling development practitioners and policymakers to enhance their strategies for food security, poverty alleviation, and livelihoods, and promote smallholder irrigation projects in particular. The present study contributes to addressing gaps in the literature by: (1) assessing farmer perceptions of irrigation scheme functionality in Masvingo Province; (2) analyzing the relationship between plot size and household income generation; (3) identifying farmers' needs and priorities towards sustainable scheme operation; (4) suggesting evidence-based plot size recommendations for policy reform.

Literature Review

Agri-Systems in Sub-Saharan Africa

Ringler et al. (2022) found that separate methods for water, food security and nutrition often lead to poor performance because actors in these systems rarely communicate with one another, which is essential. As much as Xie et al. (2018, 2014) had claimed that irrigation in SSA has many times been viewed as a significant and productive tool for increasing agricultural productivity, this was supported by Chitsungo and Yangailo (2023) who claim that smallholder farmers have received a lot of credit from continued efforts from governments and donor bodies who over the years have provided funding for rehabilitation and revitalization of irrigation systems as a way to climate-proof rural households and improve their livelihoods. However, Chitsungo and Yangailo (2023) also found that scholars do not agree that irrigation schemes are worthwhile to invest in. This idea correlates with the results of Shah et al. (2002), Van Averbeke et al. (2011), Sinyolo et al. (2014), and van Koppen et al. (2018), who argued that despite having been subjected to several investments, the performance of smallholder irrigation schemes has repeatedly come up short. Kijne (2003, 2006) noted that in arid or semi-arid areas, the use of irrigation would enhance crop yields by over 100 percent to, enhance the variety of crops, increase the income of the farmers and enhance access to food in some of these places if such areas implement the irrigation technique.

Operation Functionality and Performance of the Irrigation Methods

The concept of smallholder irrigation has been understood in terms of functionality, being that condition that, at the plot level, all farmers have an opportunity to use sufficient water for their crop production as and when they require it. Still, the meaning is different among different stakeholders. Smith et al. (2023) noted that the sustainability of irrigation business models is influenced by socio-economic, socio-ecological, and socio-econo-political environments that have implications for operation and functionality. In the smallholder irrigation business, as Araral (2005) describes and points out in Chitsungo and Yangailo (2023), a process of build, neglect, rehabilitate, neglect emerges, and the circular vicious loop continues. It is a crucial matter that merits close examination. Clemmens and Molden (2007) reported that irrigation can lead to substantial increases in crop yields for developing countries, especially if coupled with further improvements in water management and agricultural practices. According to their study, smallholder irrigation projects could be particularly helpful in lifting the standard of living.

Business Models and Plot Size Considerations

Key preferences are illustrated by regionally differentiated, context-specific, and sustainable business models across agricultural typologies (AU, 2020) and across scales (Uhlenbrook et al., 2022). Post-independence Zimbabwe introduced several initiatives aimed at de-institutionalising irrigation schemes from a regime that relied on government aid in the operation of such projects (Bolding 2004) as early as 1983, reshaping the trajectory of irrigation systems from social food security institutions to business-dependent institutions. This transfusion of irrigation management led to the development of Irrigation Management Committees (IMCs), which, in the meantime, have been running smallholder irrigation schemes. Various business models have been created throughout the global South for smallholder irrigation to make smallholder irrigation operations economically viable by improving and optimizing its performance. They are being encouraged to develop solar irrigation and pay-as-you-go irrigation business models in East Africa, such as Ethiopia (IWMI, 2020). These business models underpin good agricultural water management (AWM) with the expectation of increased biophysical water productivity (BWP) (FAO, 2022) that might, in turn, relate to economic water productivity (EWP) (FAO, 2022).

Otoo et al. (2018) underscored the importance of grasping the irrigation value chain—the economics and return on investment, technology, and finance mechanisms for developing flexible business models. Smallholder irrigation business models in Zimbabwe are: (i) Private Company model, (ii) Farm manager model, (iii) Individual farmer model, (iv) ARDA Irrigation Production Support Model (now called V30 accelerator model), (v) ZESA End User Model, (vi) Smallholder Partnerships Models, (vii) Dryland Model, Kibbutz 2Ha Irrigation model, (viii) Joint Venture Model, (ix) Irrigation Management Committee (IMC) model for groups and (x) Village Business Unit model. The IMC model features micro land units (0.1ha to 0.5ha) in smaller-scale irrigation systems that are administered only by a single farmer but share a common water infrastructure. The IMC model was the predominant configuration based on most smallholder irrigation schemes in Zimbabwe until 2020. With the re-introduction of the Control of Irrigable Areas Regulations, through Statutory Instrument 38 of 2021, the ARDA model received further impetus where all schemes are assigned scheme business development managers which is a new layer of management over IMCs established to support the consolidation of plots while developing block-based production on schemes which was a stark change from the plot based production system which afforded independent production to a few plot holders.

Training and Capacity Building

Zerssa et al. (2021) systematically examined capacity building with sustainable irrigation development as a whole, recognizing four important components: knowledge, skills, attitudes and values. They emphasised a participatory and collaborative approach used for capacity-building, with inputs from a variety of stakeholders, including farmers, government authorities, NGOs and private sector players. As part of one of their case studies in capacity building for sustainable irrigation practice in Ethiopia, they discovered the significant and severe barriers that the participants face, such as limited technology facilities, lack of adequate infrastructure, and insufficient financing needed to ensure continual levels of training and institutional capacity, which lead to continuous sustainability of irrigation development interventions that are needed over the long-term.

Research Methodology

Research Philosophy and Design

This study was guided by the pragmatism research philosophy. This paradigm was chosen because it would be compatible with the strategies used in the interpretation of research data as well as all aspects of a paradigm such as epistemology, ontology, theoretical perspective, methodology and method. Pragmatists, according to Johnson et al. (2017) cited in (Kaushik and Walsh, 2019) hold that all knowledge in the world is socially constructed, but that some versions of those social constructions more closely match individuals' experiences than others. The authors of this study used ethnography to describe the farmers' requirements, practices and benefits based on smallholder irrigation. Ethnography grants the researcher the opportunity to see the world through the lenses of the informants. This study sought to assess the effectiveness of smallholder irrigation schemes based on factors such as plot size influence on food security, household incomes and sustainable operation and maintenance of the irrigation schemes, based on the null hypothesis that there is no significant relationship between plot size and average income earnings for smallholder farmers in Zimbabwe. In the context of this discussion, the term "smallholder irrigation" is a broad term that is used to define the category of rural development projects that involve the investment in shared communal water infrastructure by governments and development partners with a thrust designed to encourage farmers to engage in irrigated agriculture in a socially cooperative manner.

Study Site

Masvingo sits amongst the ten provinces of Zimbabwe located in the drier south-eastern lowveld of the country. The province comprises an area of 56,566 km² and a population of about 1.6 million (Zimstat, 2022). Seven administrative districts are managed by Rural District Councils (RDCs): Bikita, Chiredzi, Chivi, Gutu, Masvingo, Mwenezi, and Zaka. The province lies mostly semi-arid, with minimal rainfall and with very variable, erratic, and uncertain rainfall, and so is prone to droughts. Most of the province is placed as Region 5 in the climatic and agro-ecological areas of the country. Although most of the province is usually dry, it has some of the most fertile soils for agriculture, inland water bodies, and river systems (the drainage system is dominated by the Save, Runde, Mwenezi, Mutirikwi, and Limpopo river systems), drought-tolerant and vigorous vegetation such as Mopani trees, and extraordinarily rich natural pastures. Masvingo hosts at least 54 percent of Zimbabwe's stored water. Amongst many other dams, the province has the largest inland dam named Tugwi Mukorsi dam, with an estimated irrigation potential of over 25,000 ha on its own. The primary farming activities involve subsistence production of drought-resistant cereal crops (sorghum, rapoko, millet, and a number of types of maize) and cattle rearing (including commercial cattle ranching). Because maize is produced through irrigated farming, the study of smallholder irrigation dynamics in Masvingo Province is a potential field study.

Sampling and Data Collection

A questionnaire was responded to by 181 irrigators of 14 irrigation schemes. Response selection was done using a stratified random sampling method. In keeping with the ethnographic research technique, data collection was conducted through direct verbal interaction between the researcher and a sample of smallholder irrigators in Masvingo Province (Zimbabwe). Participant observation also provided the researcher with a means to achieve this. Participants were watched as the researcher visited a variety of smallholder irrigators in a farming village near their fields to observe what they do every day for irrigation, then used their field contact for information on unanticipated outcomes. Data were collected using in-depth semi-structured interviews as well as focused group discussions. It consisted of four particular sections: (i) perception of functionality, (ii) benefits, (iii) needs, and (iv) average annual earnings. A questionnaire was used as an interview guide, but throughout data collection, the sequence of questions was amended with certain additions to wording at convenient times for the purpose of clarification of certain details. Also, the authors were open to participants sharing their personal perspectives with the researcher.

Data Analysis

Internal consistency of collected outcomes was analysed utilizing Cronbach's alpha. Questions were clustered to central themes of the study: perceptions on functionality, farmer's needs, distribution of needs, and average income earnings. The collated data was analysed to see if plot size is strongly associated with the incomes of average farmers from their plots. Data formatting and cleaning were performed in terms of imputing missing values and removing incomplete cases. Cronbach's alpha coefficients were computed using statistical software SPSS 20. According to George and Mallery (2003) and Mohamed (2016), Cronbach's alpha of greater than 0.7 is considered acceptable, confirming the internal consistency of our data. To examine the hypothesis and relationship between plot size and income generation, multiple regression analysis was performed.

Table 1 Reliability test results

Study Variable	No. of Items	Cronbach's Alpha
Perceptions on the functionality of irrigation schemes	5	.786
Plot size versus income earnings	4	.756
Alleviating poverty	4	.713
Analysis of needs	4	.712

Distribution of needs	3	.732
Overall	20	.791

All Cronbach's alphas are above 0.7, and following Mohamed (2016), this indicates good internal consistency of data; hence, the data collection tool could be adopted by other researchers for similar research themes.

Results

Perceptions on Functionality

While investigating the status of smallholder irrigation schemes in Masvingo, respondents had varied perceptions regarding the functional status of their irrigation schemes. Farmers from the same irrigation scheme would respond differently when asked whether their scheme was functional or not. These different responses triggered an investigation of how farmers define irrigation scheme functionality. Functionality in smallholder irrigation schemes was observed to be multi-layered and highly contextualised depending on the stakeholder's lens. Farmers had a bias toward plot-level functionality; in their context, once they had access to water in their field, they considered the scheme to be functional. Extension workers took a bias toward the Irrigation Management Committee (IMC)—once a scheme was led by a vibrant IMC, extension workers viewed the scheme as functional. Irrigation experts looked at provincial statistics.

Interviews with farmers revealed that as long as water reached their individual irrigation plots, the irrigation scheme could be defined as functional. This individual plot-level perspective resulted in 81% of farmers considering their schemes functional. However, a section of farmers indicated that although water could be reaching their irrigation plots, issues of leakages, shortages of water during the peak of the dry season, and partial abandonment of irrigation schemes during the rainy season informed their responses to categorise their respective irrigation schemes as non-functional. When asked about provincial-level functionality, only 57% indicated that above 3,000ha was functional, representing a significant disconnect between plot-level and scheme-level perceptions. Twenty-six percent were of the view that between 50% and 60% of the land under smallholder irrigation was functional, while 15% believed irrigation schemes were moderately functional. Only 2% indicated that at least 7,000ha was functional.

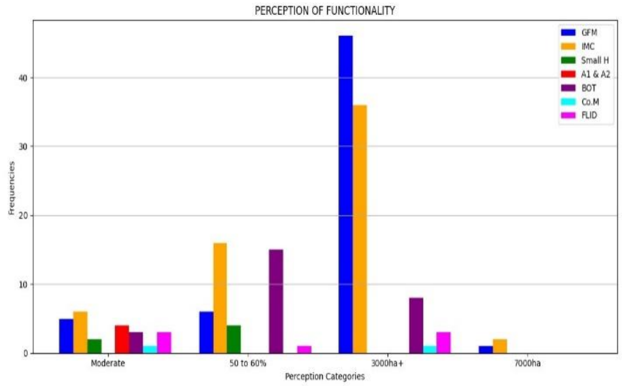

Fig. 1 Perception of functionality according to farmer classification.

Source: Authors

The Moderate perception of functionality in irrigation indicates that stakeholders perceive the effectiveness of irrigation systems or practices as neither too high nor extremely low

50% to 60% indicates stakeholders like farmers, agricultural and policy makers that the usability of the irrigation system or practices was moderate enough, but there were considerable areas to improve.

3000ha+ participants feel that functional irrigation is around 3 000ha but not more than 7 000ha

Functionality in irrigation is on a scale exceeding 7 000 hectares among the stakeholders at 7000ha

The fact that the majority of respondents were of the view that not every scheme was functional indicates a need for farmers to be supported with rehabilitation assistance, including operation and maintenance training. The above difference between plot-level optimism (81%) and provincial-level evaluation (57%) demonstrates some major discrepancies that exist in measuring and defining functionality from the perspectives of various stakeholders. There is no good scheme that exists in any way, shape, or form, according to almost all of the surveyees, implying the need to help farmers through rehabilitation efforts, including training on operations and maintenance. The above difference in perceptions is an example of the gap that exists between plot-level optimism (81%) and provincial-level evaluation (57%).

Benefits from Irrigated Agriculture

The benefits that farmers derive from irrigated agriculture cannot be underestimated. Respondents indicated that produce from their irrigation plots was more than enough to cater for their daily food needs. The growing of crops such as maize, sugar beans, and wheat in these irrigation schemes was primarily for household consumption. All farmers (100%) affirmed using their produce for household consumption. However, approximately half of the respondents (52%) acknowledged that after providing for their families with food produced from irrigation plots, excess produce was sold locally. These farmers used income from sales primarily to pay for children's school fees (52%), with smaller proportions using earnings for livestock feed (13%) and procurement or repair of irrigation equipment (7%). The differences in farmers only producing for household consumption versus having excess produce to sell can be attributed to differences in plot sizes as well as the number of people per household. Irrigation farmers with an average of 0.5ha were able to produce beyond household consumption for at least one season in a year, as the other season was meant for the production of cereals (maize) for household consumption.

Farmers within a block irrigation system—for example, where a farmer possesses 0.5ha in three blocks—were more advantaged as they could produce more and a variety of crops during the same season. Farmers with plot sizes below 0.5ha were only able to produce for household consumption with no excess for sale, as their production was constrained by plot sizes. Farmers with a household composition of fewer than five people indicated having the possibility of having excess to sell, unlike those with more than five people in one household. Analysis of how farmers deployed their earnings revealed that 31% of proceeds from irrigated farming were used for food provisions, 25% for fees (mostly school fees), 12% for livestock-related provisions, and 15% to purchase equipment. The rest of the earnings were used for petty cash (2.4%), clothing (1.8%), and employment costs (3.66%). This trend emphasizes that farmers' own labour contributions through self-employment are not ascribed any financial value, similar to findings by Giordano and de Fraiture (2014) in their study in South Asia.

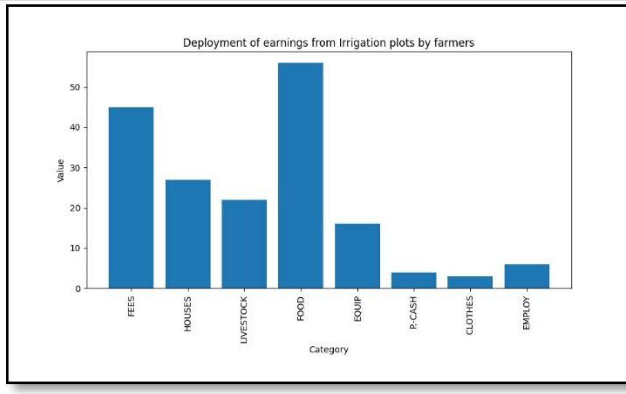

Fig. 2 Deployment of earnings from irrigation plots by farmers

A key observation is that earnings from this enterprise are largely used to meet subsistence demands and address poverty concerns, rather than generating surplus capital for reinvestment or wealth accumulation. This pattern is directly related to the constraint of small plot sizes, which limits the potential for commercial-scale production.

Plot Size and Income Generation

A highly significant and positive correlation ($p<0.001$, $R^2=0.596$) was obtained between plot size and income generation, hence leading to the rejection of the null hypothesis. The statistical significance shows that plot size is a major determinant of farmers' income in small-scale irrigation schemes. Farmers with plots below 1ha were earning ≤USD1,300 per year, where most of their income was spent on meeting their basic subsistence needs, which include buying food, paying school fees and purchasing other necessities. Such income levels make these farmers survive from day to day without any room for capital accumulation and investments.

There was an identified threshold of viability and successful commercial operations: farmers with plot sizes of 2.4–2.6 ha would be earning optimal income levels of USD 3,500 – USD 4,000 per year. This income level enables farmers to move beyond subsistence to: (1) maintain and improve irrigation infrastructure, (2) invest in quality inputs and equipment, (3) diversify production beyond staple crops, (4) access credit and financial services, and (5) contribute meaningfully to scheme-level governance and maintenance.

Farmers operating at intermediate plot sizes (1- 2 ha) showed incremental income improvements, but remained constrained in their ability to operate as viable commercial enterprises. The data clearly demonstrates that current average plot allocations of

0.5ha severely limit both individual farmer prosperity and collective scheme sustainability.

This study affirmed that there is a statistical link between plot size and income earnings. Arguably, there is a general increase in earnings with the increase in plot size. In making that conclusion, other observations were noted regarding the influence of crop types, poor soil quality, varieties, maturity of markets, scheme accessibility, and farmer competencies, amongst other factors. Figure 3 below shows a trend of average earnings in relation to plot sizes by farmers.

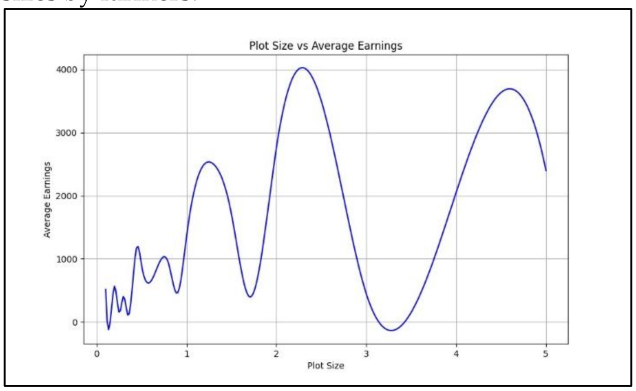

Fig. 3 Relationship between plot size and average earnings

The study observed a notable increase in average earnings with every increase in plot size. At plot sizes below 1(ha), it was noted that farmers struggled to earn beyond USD 1300 per year, even after considering all the known factors. Notably, there was a general linear relationship between plot sizes and average incomes. From Figure 8, it is evident that farmers with plot sizes below 1ha do not exceed USD 1,500 income per annum, and for farmers to achieve incomes in the region of USD 2,500 to USD 3,500 per annum, the optimum plot size needs to increase to a region of between 2.3 ha and 2.5 ha per household. This research therefore proposes a review of the smallholder irrigation scheme plot holder allocation from the current 0.5ha per household to 2.5ha per household in order to ultimately address income earnings, livelihoods, poverty and sustainability concerns. These findings align with broader literature on agricultural economics, which consistently shows that farm size affects economies of scale, access to markets and credit, adoption of improved technologies, and overall productivity (Barrett et al., 2010; Sheahan and Barrett, 2017). The 4.2- 4.5 ha threshold identified in this study provides an empirically grounded policy target for irrigation plot allocation in Zimbabwe's semi-arid regions.

Discussion

The Paradox of Functionality

This research unveils a critical ‘functionality paradox’ for Zimbabwe’s smallholder irrigation sector. While 81% of the farmers feel that their schemes are functional at the plot level, 57% think that provincial irrigation schemes work. The difference of 24 percentage points also brings out sharply divergent views on functionality among stakeholders and its implications for the formulation of policies, investment framework and governance structures. In this regard, the farmers' utilitarian approach to assessing the functionality of a scheme means that it either provides them with water in their plot or fails to do so. The extension workers take into consideration the governance aspect and hence judge the functionality of irrigation schemes through the vibrancy of IMC, while the planners base their evaluation of functionality on statistical information from the provincial irrigation schemes. Therefore, the inconsistency in values leads to blind spots in policies, as schemes that succeed fail simultaneously based on the criteria for success. This inconsistency also suggests that the present evaluations of functionality do not help much in ensuring the viability of schemes. An irrigation scheme becomes sustainable when it fulfils various requirements, namely providing water to the farmer, having an effective governance structure, being economically viable, and mitigating poverty and enhancing food security. Combating these positions calls for co-development of composite functionality indices by combining technical, economic, social and institutional aspects.

Plot Size as a Fundamental Limitation

Regression analysis proves that plot size is the most crucial determining factor for the economic viability of an irrigation scheme ($R^2=0.596$, $p<0.001$). Existing 0.5ha allocations leave farmers in a state of subsistence and produce less than enough income (≤USD1,300) for investment in the scheme, the purchase of inputs or the development of their households beyond just basic survival. Thus, this result goes against the dominant philosophy — democratizing irrigation access — which has been the Zimbabwean state irrigation policy approach since independence. The IMC model's micro-plot approach (0.1-0.5ha) was developed to maximize the number of beneficiaries (limited irrigable land) in a maximum of households framed to ensure social inclusion and equity principles. Although well-intentioned, this approach has unwittingly turned farmers into a poverty trap, with only limited land left to create a living wage, with the dependency on the development of government support and cycles of donor rehabilitation. The 2.4- 2.6 ha optimal limit found by this investigation, which increases 3.8–5.2 times above the normal allocated threshold. This observation parallels the global evidence of the industry value with respect to minimum farm sizes for commercial farming in semi-arid areas. Dorward et al. (2009) demonstrated that to achieve commercial viability of smallholders, sufficient land is needed, and the extent of such land must enable: (1) fixed cost to be diffused over sufficient production volume, (2) investment in productivity improvement technology to enable scale-up, (3) to reduce seasonality and fluctuations, and (4) to produce surplus for savings and reinvestment. But expanding plot sizes into 2.4-2.6 ha makes challenging equity trade-offs. Because its total irrigable area is fixed, larger plots mean fewer beneficiaries. Considering the current beneficiary cohorts (averaging 0.5ha) being allocated optimal plots (average 2.5ha), total beneficiaries numbers would decrease by around half. This problem is a basic policy dilemma: maximize the number of beneficiaries at the level of subsistence, or maximise beneficiary prosperity at reduced numbers? The findings of this study are highly supportive of the latter, but recognize the political and social complexities within such reform.

Breaking the 'Build-Neglect-Rehabilitate' Cycle

The build-neglect-rehabilitate-neglect cycle in smallholder irrigation discussed by Araral (2005) very closely matches the irrigation history in Masvingo Province. The analysis of provincial irrigation schemes shows repeated occurrences of similar infrastructure that continues to be rehabilitated through donor-funded methods while never addressing the underlying sustainability considerations. The paper suggests poor plot sizes as a driver of this vicious cycle. Farmers who cannot generate income in their plots cannot provide for their own interests, but they cannot generate the economic incentive to maintain the scheme infrastructure. Maintenance slumps, production decreases, and schemes slip into the 'neglect' phase. Donor rehabilitation restores the infrastructure but does not deal with the inherent economic viability constraints that ensure future failure. Not only does infrastructure rehabilitation need to be reformed, but this is the key to breaking this cycle. Farmers with 2.4-2.6ha plots producing nearly USD4,000/year do have both capacity and reward for scheme maintenance. They can make maintenance contributions for maintenance needs, value the retention of the infrastructure, protect their income as a source of income, and possibly have access to credit for the improvements to mechanization and new technologies that can make them more productive. This sets up a virtuous cycle - you have enough income to maintain, maintain production, and productivity sustains income. But plot size reform alone is not always enough. The adoption of Statutory Instrument 38 of 2021 and the ARDA Vision 2030 accelerator model reflects an awareness of shortcomings within the business model, although operational challenges remain. A sustainable reform requires an integrated package: optimal plot allocation, strengthening governance frameworks and extension support, better market linkages and access to financial services (Scheumann et al., 2017). Optimization of the plot size builds an economic base, but reform should go hand-in-hand with the process to allow for sustainability.

Policy Implications and Reform Pathways

A basic policy transformation in Zimbabwe's irrigation needs to be undertaken as a result of this research. Existing policies that focus on maximization of beneficiaries rather than beneficiary prosperity need to be revamped and re-focused in the direction of metrics based on science on sustainability. The National Accelerated Irrigation Rehabilitation and Development Strategy (2020-2030) is a policy window for enacting an undertaking of this kind. Recommended policy reforms include: (1) Minimum viable plot size of 2.4ha-2.6ha for new irrigation developments and progressive consolidation of existing schemes where possible; (2) Strengthen Control of Irrigable Areas Regulations (SI 38/2021) to enforce sustainable management practices and to prevent subdivision of the plot; (3) Develop graduated support package that considers the different capabilities of farmers and provide ways of exit for displaced farmers, with business development support for continuing farmers; (4) Reform the governance model of IMC to commercial cooperative based and managing professionals; (5) Integrate irrigation development and comprehensive planning for rural development, as well as the market construction, raw material processing, and industrial value chain linkages. Implementation problems should not be overlooked. Plot consolidation faces numerous possible problems, such as entrenched beneficiary expectations, political resistance against decreasing the number of beneficiaries, weak land management systems, and elite capture issues. Reform success requires clear selection expectations, good grievance mechanisms, alternative sources of income for relocated farmers, and consistent political will despite the unpopular nature of the measure. There is much to learn from international practices. For example, there are important lessons to draw from the case of Kenya's irrigation reforms targeting farming associations aimed at industrial production, viable minimum plot sizes, and commercialisation (Mutambara et al., 2016). South African irrigation revitalisation programme involved infrastructure repair, farmer education, and marketing support (Tlou et al., 2006). Through agricultural water management, the integrated AWM strategy in Ethiopia helped to combine irrigation development with extensive support packages and strategies (Awulachew et al., 2010). It means that irrigation sustainability requires not only infrastructure improvements but also systemic reforms.

Equitable and Social Justice Issues

The equity issues surrounding plot size reform must not be overlooked. Some might argue that reducing the number of beneficiaries runs against the principles of inclusive development and is likely to breed an irrigation elite, ignoring the disadvantaged. This should definitely raise red flags. However, it should be noted that at present, allocation of subsistence-sized plots of 0.5ha generating an income of USD1,300 per year creates more of the same - a poverty trap where there is no way for the farmers to get out without external assistance, particularly in maintaining irrigation infrastructure. This is not empowerment and development but institutionalized poverty disguised under access to irrigation systems. It is necessary to stress that equity means opportunity, not just access to water. Farmers allocating 2.5ha plots with an income of USD4,000 can do all these things - educate, acquire assets, access finance and launch businesses - and thus move upward in the social hierarchy. What's more, even if the irrigation project is profitable, it will employ people (for instance, casual labour, inputs, transportation, processing), which will benefit the wider community because they do not own any land. This notwithstanding, one may find it difficult to think of issues related to equity. In cases where there are farmers who have been forced to abandon their land, there must be compensation, such as the offer of alternative livelihood programs, priority in alternative job provision in other development programs, phased exit program for relocating people having difficulties securing jobs to new economic means of earning a living.

Study Limitations

Several limitations should be recognized. The study was limited to Masvingo Province; its findings probably apply to similar semi-arid countries; however, caution should be exercised in making inferences about Zimbabwe's more humid agro-ecological zones. Second, a cross-sectional design captures snapshot functionality and income patterns but is unable to establish causality or longitudinal dynamics definitively. Third, income data were based on farmer self-reports, which may have reporting bias, although focus group discussions and extension worker consultation were carried out for triangulation. Fourth, the study was incomplete in determining the constraints on water availability—optimal plot sizes presume sufficient water resources, which does not necessarily hold universally. Fifth, there was no systematic analysis of market access differences between schemes, as generating income relies on more than just production volume; income generation is also based upon market integration. Lastly, a 2.4ha to 2.6ha recommendation assumes current cropping and input patterns, and intensive production systems at a smaller scale might remain commercially viable; however, until it is empirically verified, this is hypothetical. Future research should (1) follow patterns of income in response to irrigation increases or decreases in the size of plot land; (2) evaluate water resource use relative to proposal of plot expansions; (3) model economic feasibility under various types of agriculture, inputs and market opportunities; (4) look at governance transitions under IMC to commercial cooperative models; (5) measure the effects on social and economic conditions for displaced farmers under plot consolidation projects.

Conclusions

This study establishes that smallholder irrigation in Masvingo Province, Zimbabwe, faces fundamental sustainability challenges rooted in inadequate plot size allocation. The fact that schemes are viewed as functional where water is received by the plot farmers (81%), and the provincial analysis (57% functional) as well as the 'build-neglect-rehabilitate' cycle indicate underlying structural deficiencies. The correlation between the size of the plot and income generation ($R^2=0.596$, $p<0.001$) indicates that the current average allocation of 0.5ha condemns the farmers to survive with income generation levels not enough for scheme management and input costs (USD1,300). For maximum income generation of USD4,000 for sustainable irrigation operations, 2.4ha-2.6ha should be the plot size, which is four to five times more than the current size of 0.5ha. To break the cycle of deterioration and donor rehabilitation, the following measures need to be taken:

1. Minimum viable plot size of 2.4 ha-2.6 ha in new development and consolidation, where possible in the existing schemes
2. Governance improvements in terms of control of irrigable areas regulations (SI 38/2021) and move away from IMC to commercial cooperation models
3. Irrigation development with a package of support services including extension, marketing, financing and value chain development
4. Providing alternative livelihood support for farmers displaced through plot consolidation, ensuring equitable transition processes
5. Developing composite functionality metrics integrating technical, economic, social, and institutional dimensions to guide monitoring and evaluation

Such reformations run contrary to the common misconception that irrigation is basically a social approach aimed at maximising beneficiaries without consideration for viability. It has been proven that the allocation of subsistence levels leads to entrenchment in poverty rather than eradication and thus consumes development funds in continuous rehabilitation. Transformative change calls for political will to pursue sustainable development through evidence rather than beneficiary maximization which is politically convenient. On the other hand, the status quo is certain to keep farmers in a perpetual state of subsistence, deteriorating infrastructure and ultimate failure of the irrigation industry. Zimbabwe's irrigation development is at a crossroads; choose transformative reforms to make irrigation a means from poverty to prosperity or stick to the vicious circle of 'build-neglect-rehabilitate'. Irrigation development in Sub-Saharan Africa is facing the same problems: huge investments yet low returns, and the sustainability path is not clear. These results constitute an empirical basis for evidence-based reforms in policy within the region. Finally, economic feasibility is what makes sustainability possible in irrigation. Irrigation schemes have to be profitable enough for farmers to keep up their infrastructure and make productivity gains, and thus prosper. The present-day micro-plot distribution system undermines this very economic feasibility. Optimal plot size reform, even if politically difficult, is the only sustainable way out – to turn irrigation into an asset rather than a problem.

Conflict of Interests

No potential conflicts of interest are expected in the study.

Confidentiality Statement

This document contains confidential information that must not be disclosed to anyone other than the Sponsor, the Investigator Team, the host organisation, and members of the Research Ethics Committee, unless authorised to do so.

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