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ÉVA PÉK

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KAPOSVÁR CAMPUS

FACULTY OF ECONOMIC SCIENCE

THE DOCTORAL SCHOOL OF MANAGEMENT AND ORGANIZATIONAL SCIENCE

Head of Doctoral School

PROF. DR. FERTŐ IMRE DSC

Member of the Hungarian Academy of Sciences

Supervisor

PROF. DR. FERTŐ IMRE DSC

Member of the Hungarian Academy of Sciences

POOR FARMERS AND IRRIGATION:

ALTERNATIVE METHODS FOR MEASURING THE DRIVERS AND THE BENEFITS OF THE PARTICIPATORY IRRIGATION MANAGEMENT IN A DEVELOPING COUNTRY

Written by

ÉVA PÉK

KAPOSVÁR

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Acronyms

ATE – Average treatment effect

BCWUA – Branch Canal Water User Association

CAADP – Comprehensive Africa Agriculture Development Programme

CDF - Canonical discrimination function

CPR – Common pool resources

FAO – Food and Agriculture Organization of United Nations

FPI – Farmers Participatory Index

GDP – Gross Domestic Product

GoU – Government of Uganda

ILO – International Labour Organization

IMT – Irrigation Management Transfer

IPTRID – International Programme for Technology and Research in Irrigation and Drainage

IWMI – International Water Management Institute

IWRM – Integrated Water Resource Management

MASSCOTE – Mapping System and Services for Canal Operation Techniques

MENA – Middle East and North Africa

NAP – National Agriculture Policy

NDP – National Development Plan

NIP – National Irrigation Policy

NN – Nearest Neighbour matching

NWP – National Water Policy

O&M – Operation and maintenance

OLS – Ordinary least square

PIM – Participatory Irrigation Management

PSM – Propensity score matching

PPMWF – Pro-poor management of water for farming

PRISMA – Preferred reporting items for systematic reviews and meta-analyses

RAP – Rapid Appraisal Procedure

SDG – Sustainable Development Goal

SML – Semiparametric maximum likelihood

SNP – Semi-nonparametric

SSA – Sub-Saharan Africa

UGX – Ugandan schilling

USD – United States Dollars

WD – Water demand

WS – Water supply

WUA – Water User Association

1. INTRODUCTION

Growing global challenges related to the malnutrition and the food insecurity required new approaches in the agricultural production by the beginning of the mid-20th century (Hamada and Samad 2011; Ameen and Raza 2018). In response to such challenges, the leading organizations initiated Green Revolution to significantly increase the productivity of agriculture through a set of technology transfers in developing countries (Cleaver 1972). Green Revolution also entailed a considerable expansion of irrigation facilities, resulting annual 2.5 percent increase in irrigated lands in Asia (Hazell and Ramasamy 1993; Hamada and Samad 2011). The annual cereal production more than doubled, and most of the countries achieved self-sufficiency in the continent (Masters et al. 1998; Falcon 1970). However, the degree of poverty-reducing impacts varied widely amongst regions. Despite the considerable impact in Asia and partially in Latin-America, the merits fell short of their potential in Africa (Mosley, 2002). The transferred measures still appeared inappropriate in Sub-Saharan Africa due to unsuitable seed varieties, strongly centralized and national-scaled policies, and lack of human and institutional capacities (Dawson 2016; Evenson and Gollin 2003; Denning et al. 2009). Likewise, the irrigation expansion remained far below its potential. Depending on the approach of global inventory, it is estimated that only 5-7 percent of the cultivated lands is under agricultural water management in Sub-Saharan Africa as of today, meanwhile such ratio reaches up to 43 percent in Asia (Abrams 2018; FAO 2011). Another drawback of exploiting irrigation potential is that only 5.2 million ha is actually irrigated from the 7.1 million ha land equipped for irrigation in the same region (World Bank, 2012). Such underdeveloped irrigation sector is one of the main causes of the globally low yields. Sub-Saharan Africa is expected to experience a rapid irrigation expansion in the coming years, reaching up to 100 percent increase by 2050 compared to the baseline in 2010 (FAO 2020-a). This increase is required to feed a population growth never experienced before. It is well understood that irrigation development is the cornerstone of food security, economic growth and climate change adaptation. Adequate irrigation management substantially contributes to multiple Sustainable Development Goals (SDG) then, most importantly to SDG1 – eradicating extreme poverty, SDG2 – ending hunger and achieving food security, SDG6 – clean water and sanitation, SDG13 – combatting climate change and its impacts. Furthermore, sustainable water management has a cross-cutting and direct impact on almost all SDGs. Nevertheless, the current irrigation schemes are still underperforming in delivering reliable, adequate and equitable water services, thus resulting a setback for the already achieved objectives of irrigation development (ElShaikh 2018; Svendsen et al. 2009; Alcon et al. 2014; Bumbudsanpharoke and Prajamwong 2015; Woodhouse et al. 2016).

From the 1970s, the emerging challenges forced decision-makers to revisit the necessary building blocks of the irrigation development. Such challenges were the increased food demand by growing population, the reduced governmental budgets to finance irrigation management, the competition amongst different water user sectors, the poor operation and maintenance (O&M) level of irrigation systems and the rising concerns about environmental issues (FAO, 2007-a). Most of the previously established irrigation schemes were financed and operated merely by state authorities, meanwhile, farmers were crowded out of management responsibilities (Angelakis et al. 2020). The dissatisfaction related to irrigation performance rose rapidly in the 1980s. Carter (1989) defined an early diagnosis of common problems concerning the African irrigation schemes and concluded five major limitations: the extremely high capital costs, the overestimated and exaggerated gains, the unexplored social reality, the lack of management skills and responsible human resources, and the neglected O&M (Carter 1989). Results of several other appraisals reinforced the concerns related to the institutional weaknesses, owing to the over-centralized and bureaucratic management (Barnett 1984; Awulachew et al. 2005; Ofosu et al. 2014). This recognition shifted the traditional management mechanisms to a more integrated community-based design. Management transfer, therefore, grew into a key strategy (Wong 2012; Khadra et al. 2017; Playán et al. 2018; Vermillion and Sagardoy 1999; Agrawal, 2003; Ricks, 2015). According to the varying implementation modalities and phases, the management transfer is labelled differently such as irrigation management transfer (IMT), participatory irrigation management (PIM), turnover or responsibility transfer. The technical differences between these definitions are discussed by many authors, still, the definitions are commonly used interchangeably (Hatcho and Tsutsui 1998, Khadra et al. 2017, FAO, 1999-b). As a first necessary step, the establishment of farmer-centred Water User Associations (WUA) spread worldwide to "bring together farmers for the purpose of managing a common irrigation scheme" (IWMI 2018; Brewer and Raju 1995). FAO (2007-a) defined the philosophy of participatory management as "increased ownership, decision-making authority, and active participation in the operation and maintenance of irrigation systems would create or force a binding commitment from water users to be more effective and responsible towards their obligations". From end-user perspective, researchers attribute several gains to the participatory management such as equal and fair water distribution, more appropriate O&M, better farming outcomes, increased sustainability and more efficient conflict resolution (Hatcho and Tsutsui 1998; Kolavalli and Brewer 1999). The management transfer is, then, considered a promising strategy for both the farmers and the state. Also, its concept is in line with the pillar of Integrated Water Resource Management (IWRM) promoting the stakeholder involvement into management.

However, the policy implementation and the actual participation of farmers remain poor and incomplete in most of the countries (Gany et al. 2018; Ghazouani et al., 2012; Ricks 2015; Huang, 2010; Yami, 2013; Moss and Hamidov 2016; Wang and Wu 2018). The challenges of translating such policy reform into an action are wide-ranging. For example, Salman et al. (Salman et al., 2020-c) concluded from a series of case studies in Egypt that a too radical turnover process can burden the unprepared farmers and affect the condition of the infrastructure (FAO- 2020-b; Salman et al. 2020-c). Cambaza et al. (2020) investigated the efficiency of management transfer in Sub-Saharan Africa, whereas the solely top-down and political approach led to a paradoxical turn away from participatory management (Cambaza et al. 2020). To what extent these results can be generalized is yet to be determined (Gany et al. 2018). Despite the fact that researchers positioned the management transfer into the centre of interest, there is a general paucity of systematic evaluation of the impacts and consistent outcome tracking (Meinzen-Dick 1996; Khadra et al. 2017; Vermillion 1995; IWMI 2006; Arredondo Salas 2004; IWMI 2002; Cambaza 2020). Senanayake et al. (2015) articulated this problem in their systematic review of management transfer impacts: “what is the evidence on which the various conclusions of IMT success or failure are based? Given the scale of IMT/PIM implementation, it is remarkable how few attempts have been made to rigorously answer these questions” (Senanayake et al. 2015). Therefore, it is necessary to establish a more comprehensive framework to measure the impacts of management transfer, with a renewed focus on scientific methodologies. Notwithstanding its expected benefits for farmers, there is a surprisingly little scientific evidence that management transfer programmes have been attaining a significant impact on farmers. A large body of research analyses the impacts via the WUAs. However, this is not sufficiently adequate approach to understand farmers' benefits given their poor actual participation in WUA (FAO 2007-b). The current literatures do not take due account of farmers' diverse background, which can substantially affect their ability to take management responsibilities, and eventually to have equal benefits. This raises a great concern on the reliability of existing impact assessments of management transfer (Vandersypen et al. 2008). Another important concern about the available literatures is that they measure the impacts merely at system level, and not at individual level. This approach, however, is not appropriate to assess the suitability of participatory programmes for livelihood improvement. In light of the previously expressed global challenges, there will be a strong emphasis on irrigation development with a stronger focus on people-centred approaches. Revisiting the concept of participatory management and supporting a unified position on its impact is of a great interest. Adding to it, such concept must be repurposed to enable the measurement of benefits at the individual level.

As water management specialist and economist, I have been involved in several international development projects and visited the most deprived areas in the world. These experiences largely shaped my research interest and objectives. Based on such experiences, I set the goal to introduce robust methods for measuring the impacts of participatory management from the poor farmers' perspective. The complex research objective requires the following specific goals:

G1: Understanding the farmers' effective role and degree of involvement into the management;

G2: Investigating the features of farmers on the basis of their participation in the management;

G3: Categorizing farmers based on their common features regarding the participation;

G4: Measuring the impacts of the participatory management on farmers.

The ultimate objective is to provide scientifically recognized results that can be translated into development projects and mechanisms. The implementation mechanism of management transfer, however, varies broadly across countries and even communities. The national legislation, cultural values, demographic trends, level of equipment and a number of other external and internal factors largely shape the implementation modalities. This research starts to unravel the complex question through a case study approach that sets the scope on Uganda. The case study approach, however, does not entirely constrain the applicability of the results and the conclusions in a broader context. The approach is piloted and demonstrated in Uganda, but it aims at providing a set of evidence-based scientific methods for future impact assessments. It is expected that the approach allows for methodology transfer and scale out, in support of the future research.

I am Hungarian and my most beautiful cultural heritage is certainly my mother tongue. I, however, write my dissertation in English, because I would like its messages to reach out to the ones in an immense need: to the poorest and most vulnerable.

2. LITERATURE REVIEW

The current chapter involves an increasingly widespread method of the literature review. A systematic review of existing impact assessments is conducted to obtain a proper stocktaking of existing literature and draw conclusions from the measured effects of IMT/PIM. To the best of our knowledge, no systematic review has been conducted to synthetize the results of management transfer from farmers' perspective. The chapter starts with the introduction of the systematic review by giving a stepwise overview on the process. The chapter discusses the general observations about the compiled database and includes also the meta-analysis of the most important findings. Finally, a consistent link between the systematic review and the research objectives is established.

2.1. The systematic review process

Systematic review is a structured type of literature review "that uses systematic and explicit methods to identify, select, and critically appraise relevant research, and to collect and analyse data from the studies that are included in the review" (Cochrane Collaboration 2005; Higgins 2019). Siddaway et al. (2019) defines systematic review alternatively as "comprehensive search to locate all relevant published and unpublished work on a subject; a systematic integration of search results; and a critique of the extent, nature, and quality of evidence in relation to a particular research question" (Siddaway et al. 2019). Due to its interdisciplinary nature, water management brings together different fields of sciences such as engineering, hydrology, biology, environment, sociology, development economics or health (Briscoe 1997; Lund 2015). The literature review of such diverse concept, then, requires specific criteria in order to ensure the appropriate scope of the research. The enormous growth of literature related to the smallholder irrigation and participatory irrigation management exacerbates the general uncertainties related to appropriate methodology, cross-cutting research questions and conflicting findings. Systematic review has been considered a popular methodology to resolve this issue through collating research results on the basis of pre-set eligibility criteria. In a simplified manner, systematic review involves i./ the identification of relevant works addressing a pre-defined research question, ii./ the review of the identified research and iii./ the synthesis of findings (Pollock and Berge 2018; Robinson and Lowe 2015; Hanley and Cults 2013; Newman and Gough 2019; Tranfield et al. 2003). One of the widely used protocol for registered systematic review is the so-called Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) (Moher et al. 2009). PRISMA defines a checklist of items to include in the reporting. While the items are recommended to an all-embracing review, some of them might not be relevant in this dissertation. Figure 1 shows the steps of the systematic review involved in the research. The descriptions and results of the steps are presented in the same structure.

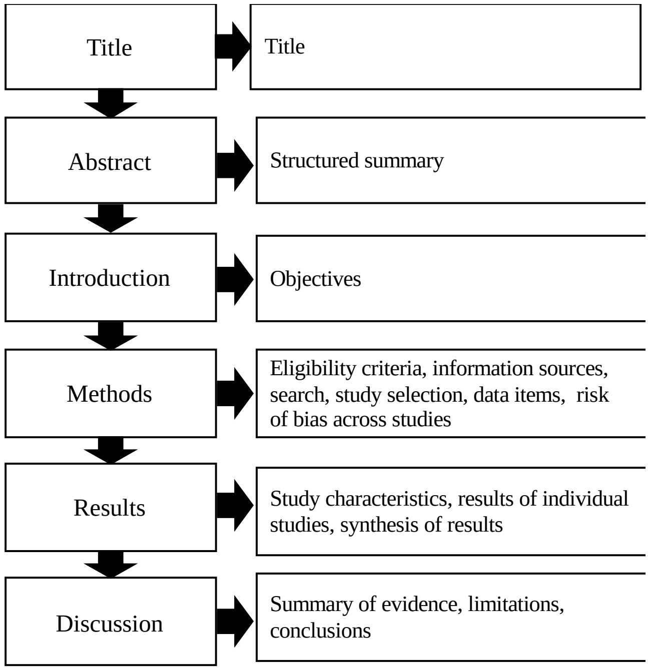

Figure 1: Simplified flowchart of the systematic review (source: Moher et al. 2009)

2.1.1. Objective of the systematic review

The literature about the measured impact of management transfer on the farmers is dwarfed by the assessments concerning the state as the primary beneficiary. As the initial concept of management transfer was stemming from the need of relaxing the central budgetary burden, the early diagnoses set the scope on the governmental gains. However, the success and sustainability of management transfer depends almost exclusively on the willingness of the farmers (van Buuren et al. 2019; van Korff et al. 2012; Singh et al. 2014). Farmers, on the other hand, are expected to be driven by financial gains. As one of the most comprehensive assessment of management transfer by International Water Management Institute (2009) states "farmers are not necessarily interested in cooperative action unless and until the benefits of cooperation exceeds that of costs" (IWMI 2009).

Setting the research scope merely for farmers is necessary then. The objective of the systematic review is to analyse the literature concerning the farmer's gain. As direct response to this concern, the following research question is proposed: "What are the measured effects of IMT/PIM on smallholders in developing country context?"

2.1.2. Eligibility criteria

In first step, the inclusion criteria are set to obtain high-quality literatures that respond to the research question and allow for cross-comparison:

i./ The first criterion is related to the target group of the impact assessments. All too often, the performance of farmer-managed systems is analysed through the WUAs, which results in wrong perception of the success of management transfer. Although WUAs are theoretically established by farmers, it is not the case in reality. State-prompted establishment of WUAs causes resentment between policy-makers and farmers. As Goelnitz and Al-Saidi (2020) describes the IMT process in the most argued irrigation scheme in the world, Gezira in Sudan: "The awareness about the reform benefits was low while farmers were not adequately incentivized to participate in the WUAs operation" (Goelnitz and Al-Saidi 2020). Therefore, it is important to distinguish the different management layers. There are normally three interdependent layers, which are typical affected by the management transfer: government, irrigation agency (WUA) and farmers. The impact might be positive on one layer but negative on another. It has become clear that management transfer programmes successfully relaxed the budgetary pressure on the state. It is less clear though whether it has come at the expense of poor farmers or not. Current literatures conclude that although farmers are the centre of IMT/PIM processes, their benefits are either insufficiently investigated or underreported (Gari et al. 2017; Vandersypen et al. 2007; Mwamakamba et al. 2017; Starkloff and Zaman, 1999; Skogerboe et al. 2007; Svendsen et al. 2000). For example, increased farmer fees significantly contribute to the financial sustainability of WUAs. On the other side, it means additional financial burden on farmers, which may adversely affect farm profitability. Therefore, the first inclusion criterion of existing literatures is that only papers measuring the impact of IMT/PIM on farmers are selected.

ii./ The second criterion is related to the potential magnitude of the impact. In line with the subject of the dissertation, the research frames irrigation development in pro-poor context and narrows the geographical scope for developing countries. The direct link between poverty reduction and irrigation has been already proven. Nevertheless, the poverty-reducing impact – as it relates to the technical and management design – can substantially differ from one to another (Hussain and Hanjra 2003; Hussain 2007; Lipton et al. 2003; Chitale 1994; Lipton 2007; FAO 1999-a; Smith 2007; IWMI 2005). Giordano et al. (2019) conducted systematic review of the impacts of irrigation on poverty. The authors listed six major findings that build direct relationship between irrigation and poverty. From these findings, the second point articulates that "irrigation has been strongly associated with decreases in poverty, particularly amongst direct beneficiaries and urban consumers" (Giordano et al. 2019). Consequently, the second inclusion criterion of existing literature is that only research conducted in developing countries are considered.

iii./ The third criterion defines the approach of the impact assessment. Although large body of literature provides analysis of management transfer at national level, they often disregard or fail to scale down the impact assessment at beneficiary level. Therefore, the research is set to measure direct impacts on farmers through including case study-based literatures, which measure the impact through "before-after" or "with-or-without" analysis. The third inclusion criterion of existing literature is that research methodology is based on a case study approach.

iv./ The fourth criterion sets a requirement related to the research methodology. Each included article must be based on recognized research methodology, which highlights causality between the management transfer and its different impacts. Therefore, the fourth criterion is that the literature must present a research methodology with a certain rigor.

v./ The fifth criterion defines the type of included articles. International organizations, such as FAO, World Bank or IWMI are the lead global institutions in the current field of science. As the concept of management transfer arose from the twofold outcomes of irrigation development, international development agencies took the role of finding appropriate responses to the countries' requests. However, many of the institutional publications do not apply any kind of research methodologies to measure impact. Therefore, the fifth inclusion criterion narrows the selected literatures to scholarly articles[1].

2.1.3. The selection process and coding

The systematic review is conducted by two independent reviewers applying double screening method. This double screening is introduced to minimize

[1] The inclusion criterion does not completely neglect the publications of development agencies. Articles, which are also published in indexed journals and comply with the further inclusion criteria can be also included to the final selection.

the potential review bias in the selection and analysis. The articles are assessed by the reviewers individually, and results are compared. The controversial points are consulted. During the search phase, the most relevant databases are selected, which provide an access to relevant fields of sciences including development economics, agricultural economics, water, agriculture, and irrigation. Based on this requirement, ScienceDirect, Springer, JStore, Wiley Online databases were identified as information sources. Furthermore, two online libraries of FAO and IWMI are also screened to populate the database with articles that are also published in scholarly journal. The search strategy involves the following Boolean operators in conjunction: (“participatory” OR “transfer”) AND “irrigation” AND (“impact” OR “effect”) AND (“farmer” OR “smallholder”). The search is constrained to the research articles. As the management transfer programmes have been on-going since the second half of the century and early assessments of management transfer date back to the beginning of 90s, the time limit is not set.

Unsurprisingly, the search returns over 1 000 articles per database, moreover, two databases provide over 4 000 articles. The first-round screening is carried out to eliminate the irrelevant records and the duplications. Based on this screening, 183 articles are included for abstract or full text reading. In order to align the search results to the objectives of the dissertation, abstract reading is undertaken to screen the articles against the eligibility criteria of geographical scope, case study approach and research methodology. However, the first eligibility criterion requires a selection approach different to what Boolean operators can provide. A further restriction of the operators would result overly limited results. Therefore, in order to select the articles responding to the research questions, the articles are screened and filtered based full text reading. The study selections results in 39 journal articles and 3 fully compliant articles from FAO and IWMI libraries, which are also published in scientific journals. The final selection, then, involves 42 eligible articles in total. The flowchart of the screening procedure is displayed in Figure 2:

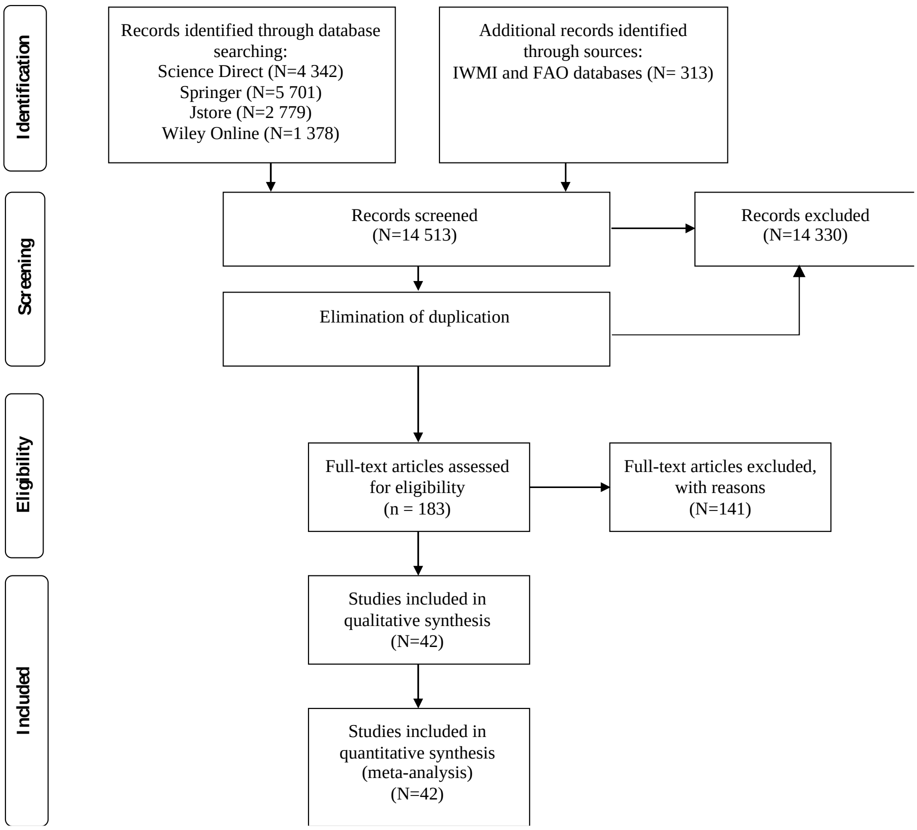

Figure 2: Flowchart of the systematic review

There are no universally accepted set of impact indicators of management transfer, which can be applied in every condition, and indicators are usually selected as per the objective of the research. The type of selected indicators, therefore, can be diverse and be related to different programme impacts. Although non-exhaustive listing of the common benefits is already presented in the beginning of the chapter, the articles are analysed to identify indicator cohorts. Such impact scopes are grouped into distinguished catchall categories. Table 1 gives a short definition of the identified impact scopes, as well as examples of potential indicators. However, the below-mentioned indicators are proposed as examples by maintaining the option for other indicators.

Table 1: Identified scopes of impact indicators

Scope	Code	Type of indicators
Productivity	1	The type of indicators related to the productive assets, production intensity, and the productivity of inputs. Such indicators are i.e., yield, irrigated area size, cropping intensity, natural resource productivity, input productivity, etc.
Efficiency and performance	2	The type of indicators related to the engineering and management efficiency of the irrigation system. Such indicators are i.e., equity, reliability, flexibility, discharge, etc.
Sustainability of the resources	3	The type of indicators related to environment conservation and environmental sustainability considerations. Such indicators are i.e., natural resource protection, ecosystem conservation, water quality conversation etc.
Cost of irrigation	4	The type of indicators related to the cost of managing the irrigation system, involving both capital and operating expenses. Such indicators are i.e., O&M costs, investment costs etc.
Profitability	5	The type of indicators related to the profit of farmers, limited to the on-farm financial measures. Such indicators are i.e., revenue, profit, production cost of crops etc.

2.1.4. The compiled databases

The articles show a diverse picture on impact assessment approaches, and only a few parameters are cross-cutting. These parameters – namely the case study title, the year, the country, the methodology, the sample size, the code and the outcome (impact) – are summarized and collated in the database. While the outcome directly answers the search objective, the other items help understand and contextualize the results. The results of the literature review are summarized in Table 2. The left columns contain the case study and publication date, and the country. The middle columns refer to the research methodology to estimate the impact and the sample size. The column related to the codes displays the catchall categories. Finally, the rightmost column shows the evidence of the impact, whether the programme resulted positive or negative outcomes.

Table 2: Summary table of the included study characteristics

Case study and year	Country	Methodology	Sample size	Scope	Outcome
Ghosh et al., 2019	India	**Feasible Generalized Least Square** regression model applied to measure before- and post-PIM performance	Study design: 6 selected states	1	**Positive** Increase in share of net irrigated area in net cropped area (from 3 to 12%) Increase in productivity of major crops (from 11 to 20%) Increase in food grain productivity (8-39%) Increase in area under high yielding varieties in 50% of investigated area (from 13 to 54%) Increase in area under high yielding varieties in 85% of investigated area (from 3 to 12%) Significant positive impact on food grain productivity in 50% of command area Positive impact on food grain productivity in 50% of command area
Uysal and Atis, 2010	Turkey	**Non-parametric t-test** to measure before- and post-IMT performance **Logit regression model** to measure the satisfaction of farmers	Study design: Bergama irrigation scheme (3 716 ha command area, 2 446 ha irrigated area, 8 136 m^3/ha water supply, 5 481 m^3/ha irrigation requirement, 1 325 users, 13 staff number)	1 2 4	**Positive** Increase in productivity of unit cropped area (from 2884 to 4 405 USD/ha) Increase in productivity of unit irrigation supply (from 0.49 to 0.57 USD/m3) Increase in cropping intensity (from 57.8 to 68%) Increase in equity in relative water supply (from 1.2 to 1.5 relative water supply) Increase in sustainability of irrigated area (from 1.03 to 1.18 ha/ha) Increase in area/infrastructure ratio (from 16.6 to 18.9 ha/km)

					Negative Decreased farmers' satisfaction
Buisson and Balasubramanya, 2019	Tajikistan	**Regression model** to estimate the performance before- and post PIM	Study design: 80 sub-districts, 25 dekhan farm (peasant farm), N =1 956 farm in 2015, N =1 855 farm in 2017	1 5	**Positive** Increase in number of crops (0.28 additional crop per farm) Increase in crop diversity including cash crops measured in Index of Diversity (by 0.13) Increase in cropping intensity (by 3.06%)
Hamidov et al., 2015	Uzbekistan	**Qualitative analysis** of the results of institutional changes	N = 63 Water Consumer Association	2	**Positive** Positive impact of effective participation on canal maintenance
Zhang et al., 2013	China	**Regression model** to compare the water productivity amongst traditional management, PIM and contracted service	Study design: 21 villages N = 315 farmers	1 5	**Positive** Positive and significant impact of heterogeneity of groups within the WUA Positive and significant impact of heterogeneity of endowments within the WUA Positive and significant impact of share of migrant heads on crop production value per unit of water **Negative** Negative and significant impact of number of households within the WUA
Yercan et al., 2004	Turkey	**Comparative analysis** of performance indicators before- and post PIM	N = 8 irrigation schemes	1	**Positive** Positive impact on irrigated land ratio (from 51 to 57%) **Negative** Decreased sustainability of irrigated land size

Mungsunti and Parton, 2016	Thailand	**Propensity score matching** to estimate treatment effect on yield, farm revenue, water use efficiency in different management scenario (between muang fai – participatory and privatized irrigation service)	N = 471 farmers	2 5	**Positive** Positive and significant impact of PIM on profitability Positive and significant impact of PIM on water use efficiency
Chaudhry, 2018	Pakistan	**Regression model** to estimate water use efficiency increase in different management scenario (old system with governmental irrigation department to new system with farmer organizations)	Study design: in 120 watercourses, 6 stakeholders are selected (5 farmers and 1 chairperson N = 720 stakeholders	2	**Positive** Positive and significant impact of farmer organization on watercourse group mean WUE
Tambudzai et al., 2013	Zimbabwe	**Comparative analysis** of the performance of Guyu-Chelesa before and after decentralization	N = 75 farmers	2	**Positive** 80% of respondents found positive impact of community-managed irrigation on food security due to better water allocation
Yohannes et al., 2017	Ethiopia	**Qualitative assessment** of irrigation performance after PIM and quantitative assessment of water distribution after PIM	N = 109 farmers	1 2	**Positive** Positive effect of pre-plant irrigation on productivity Positive effect of irrigated cropping calendar on productivity Positive effect on irrigated area size **Negative** Negative effect of pre-plant irrigation on water use efficiency

Kukul et al., 2008	Turkey	**Comparative analysis** of performance indicators before- and post-IMT	Study design Menemen irrigation scheme (22 865 ha command area, 813 km irrigation canal, 304 km drainage canal, 22 villages, 15 354 members)	1 2 5	**Positive** Increase in output per unit command (from 1 042 to 2 162 $/ha) Increase in output per unit cropped (from 1 312 to 2 455 $/ha) Increase in output per unit irrigation supply (from 0.30 to 0.41 $/m3) Increase in output per unit water consumed from 0.20 to 0.30 $/ha) Increase in irrigation ration (from 82 to 88%) Increase in relative irrigation supply (from 1.33 to 1.00, whereas 1.00 is equal to 100 % efficiency)
Abdullaev et al., 2009	Uzbekistan	**Comparative analysis** of performance indicators before and post-PIM	Not defined (N = around 60-80 farmers per WUA)	2	**Negative** Increase in number of farmers over irrigates Increase in number of farmers with insufficient water supply
Huang et al., 2010	China	**Comparative analysis** of performance indicators amongst traditional management, WUA and contracted services	N = 52 villages	2	**Positive** Increase in proportion of timely water delivery (from 57.2 to 92.4%)
Tapay et al., 1987	The Philippines	**Multiple regression model** to assess the performance of irrigation organizations related to productivity	Study design: 18 communal organizations N = 145 members	1	**Positive** Positive and significant impact of number of people involved into decision-making on productivity **Negative** Negative and significant impact of number of employees on productivity Negative and significant impact of size of organization on productivity

Ghosh and Kumar, 2012	India	**Comparative analysis** of performance indicators before- and post PIM	Study design: 22 districts N= 222 WUAs	1 2	**Positive** Increase in rice productivity (by 45%) Increase in the rate of higher value crops Increase in irrigation water adequacy Increase in cropping intensity Increase in irrigation intensity Increase in diversification Increase in crop productivity (by 57% of pulses, by 80% of oilseeds, by 40% of sugarcane, by 43% of vegetables)
Jairath, 1999	Pakistan	**Qualitative analysis** of the results of institutional changes (IMT)	Not defined	2	**Positive** Improved water delivery service Increase in canal capacity
Parthasarathy, 2000	India	**Qualitative analysis** of the results of institutional changes (PIM)	Not defined	4	**Negative** Increase in cost of irrigation
Jehangir et al., 1999	Pakistan	**Qualitative analysis** of the results of institutional changes (PIM)	N = 117 farmers	2	**Negative** No improvement in water delivery service despite of increased fees
Pant, 1998	India	**Qualitative analysis** of the results of institutional changes (PIM)	Study design: Machala Ahar district (200 housholds, 1 200 capita, 283 ha cultivated land)	2	**Positive** Improved equity through better land distribution Improved reliability and adequacy Improved water delivery service Improved sustainability
Javaid and Falk, 2015	Pakistan	**Irrigation game – artefactual field experiment**	N = 160 farmers	2	**Positive** Improved equity and water delivery service through increased common sense
Van Koppen et al., 2003	India	**Comparative analysis of** performance indicators before and post-IMT	Study design: 2 regions, 7 WUA	1 2	**Positive** Increase in number of households reporting better access to water (by 15 – 46 %)

			N = 700 farms N = 67 WUA members		Increase in cropping intensity (by 2 – 3 %) **Negative** Remaining inequity amongst upstream and downstream users
Ayella et al., 2019	Uganda	**Comparative analysis** of performance indicators between government-led and farmer-managed (PIM) schemes	N = 90 farmers	1 2 4	**Positive** Increase in productivity (by 219 – 359 kg per season) Increase in input use (fertilizer) Improved water supply Lower production cost (land rent includes O&M) Improved equity
Shindo and Yamamoto, 2017	Egypt	**Qualitative analysis** of the results of institutional changes (PIM) (strengthening Branch Canal Water User Associations)	Study design: Four pilot sites including Rash El Gharbi, Bahr el Nour, Sinnoris and Beni Ebeid (6 BCWUAs, 138 WUAs, 24 000 farmers, 10 657 ha irrigated area)	2	**Positive** Increase in satisfaction (by 70 to 80%) Decrease in number of claims by farmers (by 40 to 73%)
Svendsen and Murray-Rust, 2001	Turkey	**Qualitative analysis** of the results of institutional changes (IMT)	Not defined	2	**Positive** Decrease in number of governmental staff (by 45%)
Sam and Shinogi, 2013	Cambodia	**Regression model and descriptive statistics** of performance indicators	N = 236	2	**Positive** Significant and positive increase in farmers' satisfaction Significant and positive increase in maintenance Significant and positive increase in timeliness Significant and positive increase in adequacy

					Negative Inequity in water distribution
Salas and Wilson, 2004	Mexico	**Qualitative benefit-cost ratio** of IMT	N = 20	1 2 4	**Positive** Improved ratio of double-cropping farmers Improved water delivery service through better O&M Surplus water balance Reduced number of conflicts Improved opportunity cost by reduced time needed for irrigation delivery
Vanderspyen et al., 2009	Mali	**Comparative analysis of** performance indicators before and post-PIM	N = 22 functionaries (governmental officers) N = 43 farmers N = 10 society leaders	2	**Positive** Improved irrigation efficiency
Sam-Amooh and Gowing, 2001	Ghana	**Comparative analysis** of performance indicators before, throughout and post IMT	Not defined	1 4 5	**Positive** Decrease in cost of human expenditure (by 45%) Decrease in average production cost (by 6%) Increase in average net income (by 100%) Increase in turnover/gross return of investment (by more than 300%) Increase in financial self-sufficiency (by 200%) Increase in O&M fraction in expenditures (by 100%) **Negative** Decrease in average irrigated area size (by 36%) Decrease in cropping intensity (by 27%)

Chandran et al., 2016	India	**Comparative analysis** of performance indicators before, throughout and post IMT amongst regions	Not defined	2	**Positive** High adequacy of water service (from 10 to 45% of "always good adequacy") Proper timeliness of water service (from 2.5 to 5% of "always good timeliness") Higher Irrigation Service Delivery Index (from 11.7 to 13.2)
Samad and Vermillion, 1999	Sri Lanka	**Linear regression** to estimate the change of performance indicators	N = 50 irrigation scheme	5	**Positive** Improved gross value of output
Ghumman et al., 2014	Pakistan	**Comparative analysis** of performance indicators between centrally controlled and participatory management	Study design: Lower Jhelum and Lower Chenab Canal systems (1.29 million ha command area, 2 919 km irrigation canal)	2 4 5	**Negative** Decrease in economic delivery efficiency/share of O&M in total cost equal to 1 (from 0.41 to 0.25) Increase in cost of water (from 0.52 to 0.74 USD/m3) Increase in percentage of dry tails Increase in percentage of tails having short supply Increase in percentage of groundwater used at tails **Positive** Increase in delivery performance ratio (by 0.21 at head, by 0.02 at middle)
Mishra et al., 2011	India	**Comparative analysis** of performance indicators before and post-IMT	N = 40 experts N = 207 farmers	1 2	**Positive** High impact on irrigation in wet season (between 3.59 and 3.87 out of 5 point) High impact on irrigation in dry season (between 2.70 to 3.46 out of 5 point) Increase in cropping intensity (by 22 to 79.41%)

					Increase in size of area under irrigation (by 4.92 to 196%) Increase in irrigation intensity (by 15 to 57%) Increase in paddy rice yield (by 21.51 to 73.27%) Increase in pulse yield (by 57.14 to 61.7%) Increase in groundnut yield (by 187.95%) Increase in sugarcane yield (by 40 to 44.5%) Increase in vegetable yield (by 40 to 45.25%)
Abdelhadi et al., 2004	Sudan	**Comparative analysis** of performance indicators before and after PIM-introducing pilot project	Not defined	1 5	**Positive** Increase in cotton yield (by 87%) Increase in wheat yield (by 375%) Increase in groundnut yield (by 56%) Increase in net benefit (from 37 000 to 65 000 SD) Increase in marginal rate of return (from 73 to 119%)
Huang, 2014	China	**Instrumental variable regression** comparing PIM to contracted management	N = 47 villages	1 2 4	**Positive** Increase in share of timely water delivery (by 25%) Increase in irrigated area size (by 41%) **Negative** Decrease in amount of irrigation water (by 76%) Increase in cost of irrigation (by 37%) Decrease in yield (by 14%)
Kuscu et al., 2008	Turkey	**Comparative analysis** of performance indicators before and post-IMT	Study design: Mustafakemaplasa irrigation system (16 550 ha command area, 3	1 2	**Positive** Increase in irrigated cropped area (from 10 151 to 10 674 ha) Increase in irrigation water supply (from 68 009 to 72 401 m3/ha/season) Increase in irrigation ratio (from 58 to 62%)

			800 water users, 714 km)		Increase in relative water supply (from 1.5 to 1.6) **Negative** Increase in crop water demand (from 45 109 to 46 252 m3/ha/season) Farmers' non-approval of IMT (61.5%)
Latif et al., 2014	Pakistan	**Comparative analysis** of performance indicators between government-centred and participatory management	Not defined	1 2 5	**Positive** Increase in delivery performance ratio whereas 1 represents the optimal value (from the range of 0.7-2.2 to 0.8-1.7,) Increase in spatial coefficient of variation, whereas value closer to zero represents the optimal variation (from the range of 49-53% to 21-25%,) Increase in temporal coefficient of variation, whereas 0 represents the perfectly managed system (from the range of 3.2-13 to 0.3-7) Increase in net income (by 32%) Increase in land productivity (by 8.8%) Increase in water productivity (by 9%)
Latif and Tariq, 2009	Pakistan	**Comparative analysis** of performance indicators before and post-IMT	N = 6 distributaries	1 2	**Positive** Increase in irrigation intensity (by 25%) Increase in maize yield (by 40%) Increase in sugarcane yield (by 55%) Increase in wheat yield (by 43%)
K'Akumu et al., 2016	Kenya	**Qualitative analysis** of the results of institutional changes (IMT)	Not defined	1 2 4 5	**Positive** Improved cropping pattern with off-season commercial and subsistence crop cultivation (soya beans, kale, tomatoes, onions, maize, beans and cooking vegetables) Increase farmer income (from negative profit to 20 000-40 000 KES/crop/season/acre)

					Improved water availability (water use in off season) Increase in area under production, including previously abandoned farms (almost 100%) Reduced cost of irrigation
Latif and Pomee, 2003	Pakistan	**Comparative analysis** of performance indicators before and post-IMT	Not defined	1	**Positive** Increase in irrigated area size (by 6 to 7%)
Kadirbeyoglu and Özertan, 2015	Turkey	**Regression analysis** of farmers' satisfaction through performance indicators	Study design: 11 WUAs in three regions N = 725 farmers	2	**Positive** Increase in satisfaction of farmers
Gomo et al.,2013	South-Africa	**Comparative analysis** of performance indicators between farmers-managed scheme with world average, or before and post-PIM	N = 15 canal sections N = 32 farmers	1 2 5	**Positive** Increase in conveyance efficiency (from 76 to 86.4%) Increase in relative water supply (2.1-6.4 compared to 0.41-4.81 in benchmarking literature) **Negative** Low economic water productivity (0.070 compared to 0.077 USD/m2 in benchmarking literature) Low physical water productivity (3.5-7.8 compared to 12-20 kg/m3 in benchmarking literature)
Cakmak et al., 2008	Turkey	**Comparative analysis** of performance indicators before and post-IMT	Study design: 8 irrigation schemes, 22 990 ha irrigated area	2	**Positive** Increase in water supply ratio (from 2 to 1.5)

2.2. Results of the systematic review

The section summarizes the findings of the systematic review. Before the presentation of the impact-related results, the quality of the articles is examined to identify the potential shortcomings in current studies. The summary table demonstrates well that the implementation of IMT/PIM is diverse. The review summary, therefore, seeks similarities in the constructed article database to draw conclusions on overall features.

2.2.1. The quality of evidence

The water resource availability as a limiting factor

According to Thenkabail et al. (2009), 54 percent of the world's total area available for irrigation is supplied from surface water, 5 percent from groundwater, and 41 percent form conjunctive use with less than 15 percent surface water contribution (Thenkabail et al. 2009). Yet global inventories cannot be considered highly accurate, furthermore, regional disparities are severely limiting factors of the proper estimates (Siebert et al. 2010). However, it can be readily accepted that the groundwater use for irrigation is well below the surface water and conjunctive use. The general picture about the literatures shows similarity with this global trend. The majority of the articles analyse surface water irrigation systems, only few literatures discuss the conjunctive or supplementary use of groundwater in the command area. Such studies exist mostly in Pakistan and India. This is important from management point of view, as groundwater systems generally have less inlets and outlets. This system design can spatially concentrate the community efforts and limit the effectiveness of co-management.

The categorization of farm sizes

The research is framed in pro-poor context assuming that agriculture plays substantial role in poverty reduction. Due to economic, social and political processes, agriculture has gone through a paradigm shift in developed countries and economies under transition. The resulted structural difference requires distinct approaches to assess the contribution of agriculture to national economy. This does not become evident in the selected papers. Few papers include bigger commercial farmers, particularly in Turkish case studies, where impact assessment is introduced for both small- and medium holdings. Categorization of farmers and distinguishing subsistence and commercial farming, however, would be important. The research sets the scope for the developing countries, whereas agriculture is the proxy of national poverty reduction efforts. It focuses on smallholder farmers, who – at least partly – produce for household purposes.

Biased investigation of the irrigation scheme sizes

Despite their significant contribution to the food production chain, analyses addressing small-scale irrigation schemes are underreported. As most of the presented irrigation system developments were financed by public investment, such systems were initially planned and designed at large scale. The set of selected literatures reinforces this assumption, as over 90 percent of the articles present large-scale irrigation schemes. IWMI (2002) concludes – arguably – the issue as following: "Evaluations of the early experiences of IMT increasingly indicate that the current mode of IMT only works in respect of non-poor, market-oriented, large-scale and business-like agriculture" (IWMI, 2002). However, the prior dominancy of medium-, large-scale irrigation systems is now broken, since decision-makers have been seeking to optimise the scales of irrigation investment. As World

Bank (2010) concludes “Yet it is hard to find examples of successful, or even adequate, results from these (large scale) investments in recent years, and there have been a number of spectacular failures…” (World Bank 2010). Not only engineering but institutional efficiency requires reasonable scheme size that can be managed from limited financial- and human resources. Zhang et al. (2013) articulated that “the number of households in a WUA has a significant negative impact, thereby providing evidence for the hypothesis that a large group size may exacerbate problems of collective actions and free riding in joint water management” (Zhang et al. 2013). The significance of small-scale management should not be undervalued then. It must be also noted that the number of classification types is ample. Global versus national classification, countries with relatively small total irrigated area sizes classify the systems according to their national scale, thus leading to significant regional disparities. Consequently, the cross-country comparability of classified irrigation sizes might encounter several difficulties.

The geographical imbalance

The geographical focus of case studies is highly concentrated to a few numbers of countries. From one side, this geographic disparity is attributed to the fact that the majority of the developing world’s irrigated areas are also concentrated to as little as three countries (China, India, Pakistan). On the other side, the interest of researchers is influenced by many factors such as development processes, strategies, policies and significance of expected results. The map in Figure 3 displays the geographical distribution of case studies.

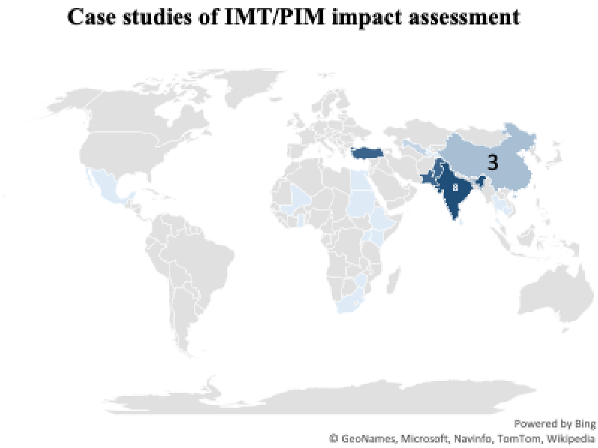

Figure 3: Geographical distribution of selected case studies

The methodology flaws

The applied methodologies must be well explicated and justified to assess the reliability of the results. 10 articles from the 42 applied qualitative methodology including one-to-one interviews, focus group interviews or expert observation. Furthermore, 18 articles conducted comparative analysis on the basis of before and post-IMT. In almost all comparative analysis, certain indicators are selected, and the change is measured as an absolute difference. These methodologies involve uncertainties, because they do not take due account of the changing conditions. For example, many policy-related programmes have been integrated in system rehabilitation or modernization projects. If PIM/IMT is part of an investment project, the measured increase can be also credited to the improved engineering conditions. The complexity of irrigation development may tempt researchers to ignore the large picture of water management and to refrain from implementing more sophisticated methodologies. Although the selection criteria address the research methodology issue by including only studies published in scholarly journals, large part of the published articles are still not built on rigorous methodology. This conclusion corresponds to the main concern of Senanayake et al. (2015), who conducted similar systematic review and concluded the following: “The overwhelming majority of studies analysed were of low quality in terms of their ability to attribute impact to IMT/PIM interventions” (Senanayake et al. 2015). In order to understand the drivers of methodology selection logistic regression is applied to set up cause-effect relationship between the applied research methodology and the following independent variables: i./ the publication year, ii./ the geography, iii./ the scope of study, and iv./ the measured outcome.

i./ Center for Global Development created a working group in 2006 to discuss and issue a new recommendation on impact assessment methods of development programmes (Center for Global Development 2006). The updated and more rigorous methods were intended to increase the effectiveness of the official development assistance. Sabet and Brown (2017) conducted a systematic review to understand the changes in trends of impact assessment publication. Authors found that “The distribution of development impact evaluations by region has remained relatively constant since 1990. In the 2010–2015 period, we witness an increase in development impact evaluations conducted in all regions, particularly in SSA with 67 per cent of all SSA studies published in the 2010–2015 period, and the Middle East and North Africa (MENA) with 70 per cent of all MENA studies published in that period” (Sabet and Brown 2017). The year of 2010 is, then, considered a turning point of new generation impact assessments. The year of publication is coded by the date of before versus after 2010.

ii./ Based on the identified geographical discrepancies, it can be assumed that information availability and benchmark studies of Africa are somewhat limited compared to the studies of Asia. Therefore, it is important to analyse the effect of location on the selected research methodology. The geographical location is coded by Africa versus Asia and other locations.

iii./ While analysing the collated dataset and the measured impacts of management transfer on farmers, the selected research method has a decisive role in the robustness of the results. Therefore, it is of great importance to understand the relationship between the measured impact and the rigor of the research method. Measured outcome is coded by negative and positive.

iv./ Finally, the quality of research methodology is coded as outcome variable. The coding remains arbitrary due to the diversity of the applied methods. The methods applying qualitative assessment and simple before-and-after analysis are considered low-rigor, while the quantitative and more sophisticated methodologies considered high-rigor. Methodology is coded by low-rigor and high-rigor.

Due to the fact that dependent variables are binary, logistic regression is applied (Sperandei, 2014). Logit model estimates the chance as odds, and the logarithm of chance is computed as following:

$$\log\left(\frac{\pi}{1-\pi}\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_m x_m$$

where π is the probability of event, namely having high rigor methodology, β is the regression coefficient and x_i is the explanatory variable, such as publication date, geography, scope of study and outcome. Table 3 represents the results of logistic regression:

Table 3: Results of logistic regression measuring the causality of methodology and other variables[2]

Methodology	**Coefficient**	**Std. error**	**z**	**P>z**	**95% Confidence interval**	
Year	0.58	0.23	2.45	0.014***	0.11	1.04
Geography	0.26	0.14	1.90	0.058**	-0.00	0.54
Outcome	-0.24	0.29	-0.82	0.41	-0.82	0.34
Code	-0.06	0.09	-0.66	0.50	-0.25	0.12
Constant	-0.85	0.37	-2.30	0.02	-1.59	-0.12

Based on the results, the publication date and geography have statistical relationship with the selected methodology, having odds ratio of 1.31 and 1.16 respectively. This indicates that publications after 2010 and publication in continents other than Africa involve higher rigor methodologies. In conclusion, the initial analyses of PIM/IMT might need to be revisited to better understand the real impacts even in larger time scale. Also, relocating the research interest to Africa might significantly enrich our knowledge on geographical differences of the realized benefits.

The scope of the studies

As previously mentioned, there are three layers of irrigation management: state, farmers' organizations (WUAs) and farmers. Nevertheless, the

[2] Note on significance levels: * corresponds to $p \leq 0.10$, ** corresponds to $p \leq 0.05$, *** corresponds to $p \leq 0.001$.

overwhelming share of existing literature investigates IMT/PIM from the perspective of the state. Although the selected articles set scope for farmers, many of them still apply a combination of indicators targeting different layers at the same time. For example, 70 percent of included articles examine the fee collection efficiency and cost recovery as relevant indicators of success. This general phenomenon might lead to the misunderstanding that the three layers can take the same advantages of PIM/IMT processes.

Summary: The main considerations of the quality of the evidence

The above-mentioned considerations underline the major shortcomings of the impact assessments. In conclusion, our research proposes the following considerations to further improve the quality of the scientific literature:

i./ Selected research approaches are often standardized regardless the type and size of farming systems. This overall concern is well-reflected by the defined sample size. Without solid understanding of hydrological and agronomic conditions, this might lead to biased assessment. Therefore, it is desirable to establish the impact assessments on various disciplines including the agriculture, the hydrology and the engineering. Identification of the resource boundaries of irrigation systems helps understand the spanning effect of different conditions on the socio-economic outcomes.

ii./ Medium- and small-scale irrigation schemes are unjustly under-represented in the current literature. Impact assessment approaches scaled at different sizes need to be introduced in order to enable an evidence-based policymaking in different contexts. This is particularly important in the case of Africa, where irrigation schemes are spatially dispersed and located in remote areas.

iii./ The geographical coverage needs a further expansion to reach well-balanced exploratory work. Although irrigation generally represents a small ratio of total arable lands in Africa, its strategic importance is increasingly growing. Furthermore, each country implementation must be context-tailored to local settings. Therefore, it is important for each country to establish its own assessment mechanism in order to exploit its irrigation potential.

iv./ Indicator selection provides a diverse and mixed picture. Although the articles are selected along restricted criteria to include only the papers focusing on farmers, many of them incorporate impact indicators on state, farmers organizations and farmers. This might result in misguided recommendations, as their interest differ from one to another. Well-targeted indicators in restricted numbers are more straightforward and they do not limit the validity of results.

v./ The overwhelming part of the articles apply low rigor methodologies and provide a doubtful credibility due to their datasets and/or their suitability for impact assessment. Retrospective approaches without controlled environment, such as comparison between past and present performances might lead to biases, as they disregard the influence exogenous interferences such as changing weather parameters, management practices, the soil fertility etc. More valid methodologies that eliminate the effects of such external factors might certainly yield more reliable results.

The abovementioned findings are considered a cornerstone of the approach and methodology selection in the dissertation. They must be eliminated to reach robust research results

2.2.2. The review results: what the literature can tell us about the impacts of management transfer

The summary of the results includes only those indicators, which confirmed either positive or negative changes after IMT/PIM implementation. The indicators with constant values are eliminated from the analysis due to methodology-related concerns. For example, an indicator can remain constant simply because it is not suitable for the given conditions. Another possibility is that the available data is not sufficient to estimate any change. Most of the articles investigate multiple indicators with different scopes. One of the significant drawbacks of the impact assessments is the complete lack of indicators related the sustainability of resource use. No article investigates impacts on sustainability and environment. This is particularly worrisome, because irrigation – if mismanaged – might have severe impact on the environment (FAO 1995; Hren and Feltz 1998; Giordano et al. 2019). Therefore, the current review does not give the opportunity to understand the evidence on the relationship of the management transfer and the status of environment. The efficiency and productivity related indicators are frequently combined, meaning that the impact is measured on both system efficiency improvement and productivity increase. Figure 4 presents the number of articles per existing scope, whereas the number of articles is calculated as per the number of involved scopes. As no indicator related to sustainability of resource use is accounted, this impact scope is not displayed in the Figure 4.

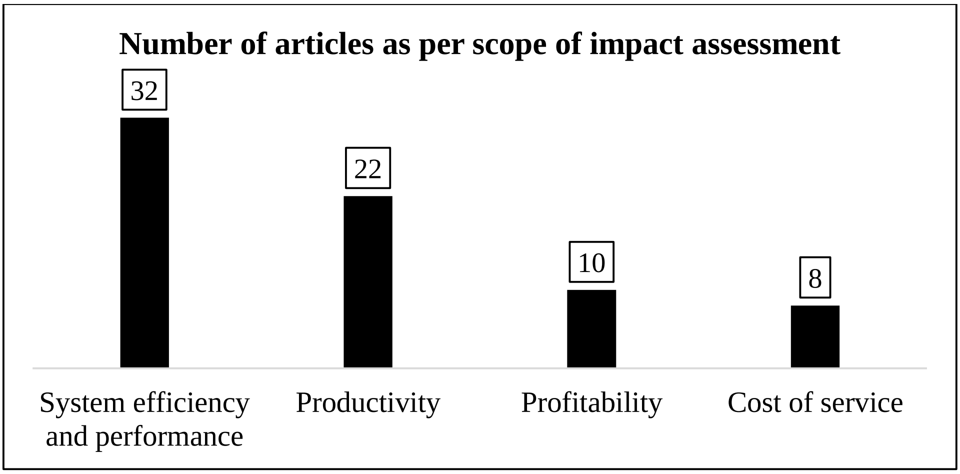

Figure 4: Number of articles as per scope of impact assessment

The picture gets even more diverse, when multiple scope per article is further broken down to the type of indicators per article. As the Figure 5 shows, 42 articles include 148 indicators in four out of five impact categories.

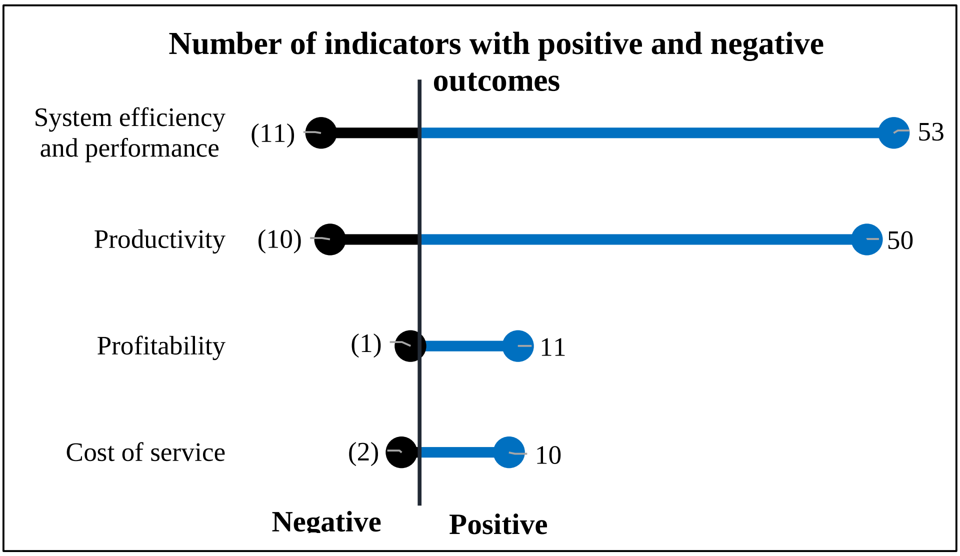

Figure 5: Number of indicators with positive and negative outcomes

The scope for 'system efficiency and performance' is more emphasized compared to others, as more than 75 percent of the articles apply some kind of efficiency and performance related indicators. Also, ‘system efficiency and performance’ is the most frequently combined category in multi-scope articles. The yield increase and profitability are wrongly under-emphasized though. As each article presents cases of developing countries, the real objectives of irrigation development in pro-poor context are strongly associated to these indicators. As Huang et al. (2010) articulate “The reform is only successful if WUAs or contracting improve irrigation management and ultimately help boost food production or raise farm incomes” (Huang et al. 2010). This uneven distribution in favour of engineering-related assessment raises several concerns about the viability of PIM/ITM as socially acceptable policy.

The “success” of IMT/PIM is undoubtably justified by the results of the articles. 84 percent of the total number of indicators have positive outcomes. The rate of negative outcomes over the total number of indicators ranges from 10 to 33 percent amongst the categories. The results per the impact scopes are summarized below:

i./ Measured “success” in the productivity increase: The majority of the productivity-focused indicators refer to the yield productivity and cropping/irrigated land intensity. 77 percent of the articles measuring productivity change apply namely these two indicators or their alternative. All case studies measuring yield increase of multiple crops show increase. So, it can be concluded that the positive change of productivity is consistent. However, the yield increase must be measured with particular caution. The exogenous factors, such as climate, rainfall, management practices, etc. should be controlled to establish robust relationship between ITM/PIM and yield with an absolute certainty. It is rather unlikely that researchers conduct their measurements in controlled environment. Future research should tackle the volatility of production conditions through approaches more suitable for field conditions, for example quasi-experimental methods. The cropping intensity might have stronger relationship with ITM/PIM, since it is driven by more reliable and equitable water service.

ii./ Measured “success” in the system efficiency and performance: The system efficiency and performance are mostly expressed with capacity- and distribution-related indicators, such as the relative water supply, the equity, and with service-related indicators such as the water delivery service. These indicators closely conform to the FAO and IPTRID (2001) definitions of high-performing water service (FAO 2001; FAO 2007-b). In fact, service-oriented irrigation management activates farmers – previously encapsulated in the “beneficiary” role – to be integral part of the scheme management. However, the engineering improvement involuntary carries additional tasks to the farmers, while it brings only indirect gains. Moreover, if the complexity of transferred engineering responsibilities outweighs the physical and financial gains, the IMT/PIM might stiffen the farmers’ disapproval. Another identified shortcoming in the presented sets of indicators is the relatively little emphasis on the equal distribution. Only six articles set scope for the equity amongst farmers, of which two cases proved negative outcomes. In future, research should put more stress on the equity-related issues. As Lipton (2007) writes “gains are more with pro-poor management of water for farming (PPMWF) and where distribution of farmland or farm water is more equal” (Lipton 2007).

iii./ Measured "success” in environment performance: None of the articles used environment related indicators to measure farmers’ benefits. Nevertheless, it can be readily accepted that the mismanagement of natural resources can generate a faster-than-expected degradation, thus limiting their sustainability (Muchara et al. 2014; Klain et al. 2014; Heikkila 2001; Kenney 1997). Degradation of resources by co-joint management has been widely argued over the last decades. The most prominent theory, perhaps, is Hardin's (1968) tragedy of common model, which states the individuals' resource use poses risk to the environment if driven by self-interest (Hardin 1968). In light of the climate change that exacerbates the adverse effects of unsustainable resource use, future research should incorporate environmental issues as a cross-cutting, horizontal policy of water resource development.

iv./ Measured "success" in the cost of service: Expenditures on system operation and maintenance (O&M) have a retroactive effect on IMT/PIM: the higher the cost, the better the performance. Since the higher irrigation cost is eventually translated into a higher production cost, the positive impact cannot be attributed alone to the increased cost of service. Accordingly, the cost of service has the highest rate of negative outcomes, whereas the irrigation cost increased as impact of IMT/PIM. However, the cost of irrigation should not be declared counterproductive, as larger expenditures might have significant positive spill-overs to the overall performance. Future research should rather measure the growth of value for money or operating expense ratio, than considering simply the absolute changes in expenditures.

v./ Measured "success" in the profitability: Increased revenues, incomes and farm gains are undoubtably the most relevant indicators to measure the farmers' benefits. However, it is probably the most difficult to set-up causal relationship between IMT/PIM and the income. The complexity of an impact assessment is driven by both field and market risks. Particularly in developing countries, the fragile market conditions might have severe negative effect on the profitability. The profitability depends on many factors such as the yield productivity, the quality of product market, prices, the seasonality, local market conditions etc. Market-related volatilities cannot be addressed by IMT/PIM policies. However, many other factors including the yield, the quality, the type of products, the seasonal supply are also the direct results of a better irrigation management. Four cases established a relationship between IMT/PIM and farmers' crop selection. In these studies, the policy shift influenced farmers to select higher value cash-crops. In fact, irrigation has paramount importance for farmers transitioning to commercial agriculture, as irrigation has yield stabilising, risk reducing and climate adapting impact (FAO, 2012; Carswell 1997). Future research must promote positive impacts of IMT/PIM on farmers' financial gains, because an evidence-based causality might be strong incentives for farmers to engage in irrigation development (Pék et al. 2019).

3. OBJECTIVES OF THE DISSERTATION

The overall goal of the dissertation is to provide a complex analysis of participatory irrigation management from farmers' perspective in developing country context. Empirical methods are presented to capture the entire process of participatory management from the farmers' engagement to the impact assessment. The major shortcomings of PIM evaluation are highlighted in the literature review, namely the underrepresentation of smallholders, the lacking diversification of irrigation scheme size, the geographical imbalance, the rigor of applied methodologies and misdirected performance indicators. Together these identified factors raise the following research questions:

- What are the key constraints and the enabling factors of smallholders' engagement in PIM?
- Is PIM viable in a small-scale irrigation scheme?
- Why are regions such as Asia more appealing for researchers than Africa – a continent in desperate need of irrigation development?
- What are the alternative methodologies that can obtain more robust results in an impact assessment?
- Are there better targeted indicators to measure the PIM impacts on farmers?

Supporting the overall goal and addressing the outlined questions, the following specific objectives are defined:

i. Qualitative assessment of the farmers' engagement in PIM and the adoption of co-joint management by farmers;
ii. Identification of the motivation pattern in participatory irrigation management, and definition of enabling factors of the participation;

iii. Characterization of farmers' groups by the participation in irrigation management;
iv. Evaluation of the effects of participatory irrigation management on farming outcomes through alternative methods.

The research applies a case study approach with the assumption that the demonstrated methodologies and results can be scaled out to a certain extent. Such approach has a merit in the current context as it enables an irrigation scheme selection that complies with the criteria of geographical location, irrigation scheme size and farm size. On the other, the case study approach is flexible enough to investigate a complex and broad topic such as the entire cycle of PIM from farmers' engagement to impact evaluation. Considering these factors, the research is conducted in Mubuku irrigation scheme in Uganda, a small-scale scheme incorporating smallholders in a deprived rural area of the country. A comprehensive description about the selected irrigation scheme is provided in the chapter 4.1. The command area. The chapter highlights the scheme features making it suitable for the research. During the research design phase, multiple challenges are encountered in Mubuku irrigation scheme, such as the data-poor environment, required interdisciplinarity and limited resources. This has led to a dissertation structure that frames the research questions in a broader perspective to provide sufficient details to support the interpretation of the results. The survey framework is presented in chapter 4.2. Data collection and research methodology. In order to acquire robust results, advanced empirical methods are applied in each part of the complex analysis, presented in the same chapter. Finally, the results of the research are presented in chapter 5. Results. The dissertation concludes with the discussion, limitation and future of the research, and presentation of new scientific results.

4. MATERIALS AND METHODS

The stepwise research methodology consists of four intertwined strands:

i. Qualitative analysis of farmers' engagement and their role in irrigation management, on the basis of the measurement of individual contribution;
ii. Semiparametric and semi-nonparametric modelling to analyse farmers' motivation pattern in participatory irrigation management;
iii. Cluster analysis for farmers' grouping on the basis of their participation in the management;
iv. Estimation of average treatment effect (ATE) of participatory irrigation management on farming outcomes.

The current chapter is structured according to the aforementioned steps. Prior to the quantitative analysis, a qualitative assessment of the co-joint management is presented as important first step to set the scene for the further analysis. It provides a straightforward narrative on the current performance of the irrigation scheme and status of PIM in the pilot scheme. This first section profiles the command area through the assessment of the prevailing conditions of irrigated agriculture and irrigation management. It introduces the applied Rapid Appraisal Procedure methodology and its application to support the research objective. In the next step, the data collection and the datasets are discussed. It also details how farmers are categorized on the basis of their individual engagement, and how this approach contributes to a more accurate assessment of participatory management. The chapter, then, describes the applied methodologies in the following order: semi- and non-parametric models to investigate farmers' motivation, clustering to obtain a typology of farmer groups and alternative estimation methods of average treatment effect on farming outcomes.

4.1. The command area

4.1.1. Strategy and policy outlook

Uganda is counted as a least developed country with increasing malnourishment due to inland migration and rapid endogenous population growth. Agriculture is still the mainstay of the economy, providing the source of livelihood to 80 percent of the population and making up 22 percent of the GDP by 2017 (FAOSTAT, 2020; Salman, 2020-a). Irrigation is key to stabilize the yield, adapt unpredictable climatic events, increase the household income and create rural employment in Uganda (Salman, 2019-a). Moreover, irrigation development has an inevitable role not only in subsistence agriculture, but in support of farmers transitioning into commercial farming. Although irrigation has a key role in boosting agricultural development, food security and income generation, the potentials of agricultural water management is currently untapped. As the country has an abundant precipitation spanning over 8-9 months a year, irrigation has received a relatively little emphasis so far. The rate of irrigated lands, consequently, accounts for 0.5 percent of its potential. Despite of its pivotal role in the national economy and the abundant water source, agriculture is still mostly rainfed. However, the devastating impacts of climate change bring the sector forward and urges decision-makers to provide adequate adaptation strategies. Since the ‘80s, the national efforts to improve the water resource management and sanitation are tremendously evolving. After the first stepstone of bringing the Water Act into force in 1997, Uganda created its National Water Policy (NWP), which heavily promoted the implementation of IWRM. The policy is split into two distinct pillars: Water Resource Management and Water Development and Use. Uganda recognizes water resource management as a development issue, which requires full participation and well-defined management responsibility of the users. NWP sets the target to increase the productivity through irrigation in order to tackle household food insecurity and malnourishment on one side. On the other side, NWP aims at achieving productivity increase while improving the efficiency of the water use. While the yield productivity covers the socio-economic objectives, enhanced efficiency ensures the sustainable use of water. Uganda aligned its National Agriculture Policy (NAP) and National Development Plan (NDP) with Comprehensive Africa Agriculture Development Programme (CAADP). Both the NAP and NDP handle investment in agriculture as a key priority defining four successive areas of the development: enhancing production and productivity; improving access to markets and value addition; creating and enabling environment; institutional strengthening in the sector. Government of Uganda (GoU) constructed its National Irrigation Policy in 2017 to reinforce its international commitment, namely Sustainable Development Goal 6 (SDG), Vision 2040, Agenda 2063 (National Irrigation Policy, 2017). The Vision 2040 assumes that "Uganda aspires to transform agriculture from subsistence to commercial agriculture through both mechanization and introduction of modern irrigation systems" and that "to mitigate local shortages large and medium water reservoirs will be developed" (Vision 2040, 2016). The Vision 2040 endows water sector with a prominent role in accelerating the development. It sets focus on the development of agriculture to fully utilize abundant water resources by creating small and large-scale irrigation schemes. The national target is the development of 567 000 hectare including schemes close to surface water resources and schemes requiring major investment in the allocation infrastructure. However, only 14 formal irrigation schemes are currently operational, of which nine are public and one is community-based scheme. All together do not cover more than 11 274 ha (Wanyama et al. 2017). Wanyama et al. (2017) carried out proper stocktaking of the existing schemes and tagged five from the nine public scheme “dilapidated” (Wanyama et al. 2017). Public schemes are owned by the government, but jointly managed with farmers’ organisations. National Irrigation Policy emphasizes the importance of participatory irrigation management, whereas farmers’ organisations are positioned in the heart of the sustainable resource management.

4.1.2. Mubuku irrigation scheme – the system features

Mubuku irrigation scheme (00°12′54″N 30°07′12″E) presented in Figure 6 is one of the fully functional public schemes undergoing rehabilitation and extension at the time of the research.

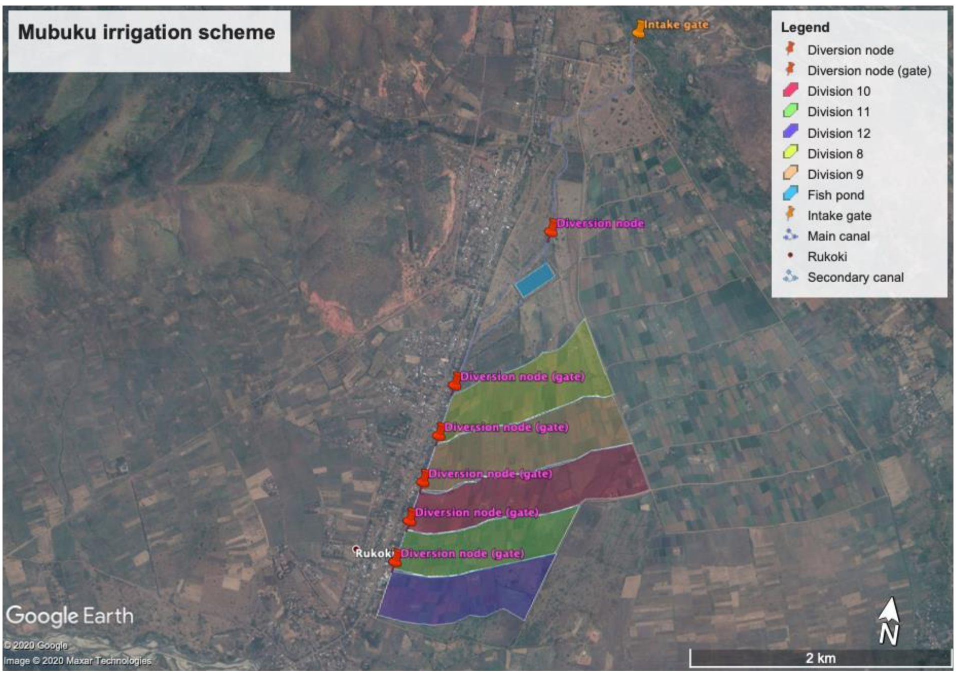

Figure 6: Mubuku irrigation system, Phase II: map view (Re-drawn from Salman et al. (2019): Field guide to improve water use efficiency in small-scale agriculture. The case of Burkina Faso, Morocco and Uganda, page 7, Figure 9. Performed with Google Earth Pro application)

It represents a typical smallholder scheme in Uganda, through which the impact of participatory irrigation management can be investigated. Mubuku is a former settlement scheme established by GoU to improve rural livelihood. The settlement scheme has multiple implications on rural development, including the absorption of unemployed, the provision of housing facilities, the supply to local markets and the household food security. However, this type of irrigation schemes entails considerable constraints, as the settled families have no history of agriculture. The capacity gaps induce spillover effects, which aggravate the efficiency and productivity shortcomings of agricultural production (Zakaria et al. 2020; Mwamakamba et al. 2017; Moyo et al. 2017).

From the original 2 000 ha designated area, only 540 ha is under production in Mubuku. The remaining part of the scheme requires the further provision of production equipment. Therefore, GoU has decided to undertake a scheme extension and roll out a large-scale construction in Mubuku. The cultivated and equipped lands are shared by 167 farmers, providing average 3.2 ha plot to each. Each farm is split into four blocks cultivated by one family. The irrigation network is built to source and distribute surface water from the Sebwe River. The system is entirely gravity-fed and phased into adjacent areas. The conveyance system is rudimentary, consisting of one main intake, lined main canal, lined secondary canals, unlined tertiary canals and field ditches.

The creation of WUA is regulated by the National Water Policy that defines WUAs as responsible organization for operating and maintaining the irrigation schemes. In Mubuku, the responsible organization is the farmers' cooperative, Abasaija Kweyamba Mubuku Farming Cooperative, which is co-managed by the state and farmers. Although most of the officers in charge are delegated by the state, some of them are paid from farmers' contribution. The cooperative integrates also the function WUA. According to the NWP, the management responsibility, as well as the ownership of an irrigation infrastructure should be gradually transferred to farmers. Such transfer is recently incomplete in Mubuku notwithstanding that it has been operating for more than a half of century.

The agricultural production

The farmers produce in double-cropping system, allowing two sequential seasons in a year. The farms are cultivated in rotation without set-aside. The typical cropping pattern includes upland rice, maize, onion, tomato, beans, mangos and other vegetables. However, maize, rice and onion make up almost the 70 percent of the aggregated production of both seasons (Salman et al. 2020-a). Based on observation and focus interview with the local extension service, it can be concluded that farmers heavily over-use inputs such as fertilizer and herbicides, while the labour costs are negligible. The farmers obtain reasonably good yields. The average dry biomass of maize reaches 3.5 ton per ha. The average yield of onion is around 11 ton per ha. However, the field experiment in the course of the research failed to obtain a meaningful yield information of rice due to unidentified infectious agents during the research period.

The value of agricultural production

The purpose of the production is both subsistence-based and commercial. In the latter case, the sale is limited to the local markets. The local market is limited to the adjacent sales points due to the poor road network, the growing competition with neighbouring countries and the lack of storing premises. The market conditions of crops fluctuate widely. Farmers have freedom of choice regarding the crop selection but are incentivized to grow maize. Within the national maize programme, GoU provides a trigger price for maize. Together with other incentives such as training, provision of inputs, purchase obligation, national information system, the maize cropping is a risk-averse farm strategy. The profitability of maize is lower than of other crops though. In case of the other crops, the farmers are price-takers, as market prices are entirely demand-driven. Due to the rudimentary market systems, farmers must face both field and price risks. The upland rice production has increasingly growing potential in Uganda, as domestic rice demand has been sharply growing (Kikuchi et al. 2014, Uganda National Rice Development Strategy, 2008). Farmers do not prefer the rice production over the maize though. The interviews with farmers proved that the main concern is the competitiveness with cheaper and higher-quality imports from Tanzania. Also, farmers have somewhat shorter experience in rice production that influences their entrepreneur mindset. The volatile market conditions cause significant differences in seasonal profitability. Weak market conditions can reduce expected profit by 50 percent. The onion production imposes even higher market risk. In downward market trend, the farmers can easily turn a loss that can be recovered only in the next season. Although onion has the highest expected revenue amongst the crops, the unpredictable market condition is severely constraining factor. Table 4 indicates the prices in upward and downward market conditions.

Table 4: Profitability of main crops in Mubuku

	Maize	**Rice**		**Onion**	
	Trigger price	Upward	Downward	Upward	Downward
Production cost (UGX/ha)	3 826 500	4 934 500	4 934 500	6 980 500	6 980 500
Production revenue (UGX/ha)	7 650 000	7 800 000	6 500 000	14 000 000	1 000 000
Profit (UGX/ha)	3 823 500	2 865 500	1 565 500	7 019 500	-5 980 500

4.2. Data collection and research methodology

4.2.1. Rapid Appraisal Procedure for performance assessment and support of data collection

It has been widely argued that water resource is key factor in agriculture, and climate change will restrict its availability (Rosegrant et al. 2009; FAO 2011; Qadir et al 2003; Pimentel et al. 1997). However, even sufficient water resources do not necessarily provide equally adequate irrigation service to all users. The high-level performance of irrigation goes beyond the assessment of water resource endowment in an irrigation scheme. Although performance has a broadly varying, it is broadly agreed that performance must be defined as per the objectives of the irrigation system in question (Gorantiwar and Smout 2005). Abernethy (1986) says that performance is “its measured levels of achievement in terms of one, or several, parameters which are chosen as indicators of the system’s goals” (Abernethy 1986). The introduction of the dissertation already highlighted the issue of the heterogeneity of the irrigation systems all over the world.

It is necessary to introduce solid benchmarking methodologies with targeted performance indicators that can provide baseline for specific improvement interventions and can be applied in different system configurations. FAO-developed Mapping System and Services for Canal Operation Techniques (MASSCOTE) approach was first introduced in 2000 (FAO 2007-b) Such methodology plugged the gap in governmental rehabilitation and modernization efforts. MASSCOTE is constructed to support performance assessment of open canal systems, starting with the actual performance analysis and concluding the potential intervention pathways of improvement. It defines universally applicable indicators to set up a baseline assessment via its first step, called Rapid Appraisal Procedure (RAP) (FAO 2011; FAO 2007-b)[3]. The RAP has been designed to provide a comprehensive overview about the baseline performance of the irrigation system in terms of hydrological, institutional management and water service performances (FAO 2001). Water delivery service is in the heart of the RAP, as FAO defines "RAP has been designed under the assumption that all employees of an irrigation project only have their jobs for one reason – to provide service to customers". RAP defines its performance indicators according to this philosophy. It is a qualitative methodology, combining field observation, interviews with focus groups

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[3] The original RAP methodology published in 2001 can be accessed in the following website: http://www.itrc.org/reports/rap041803.htm. The RAP is undergoing a development by FAO in the time of the research. Mubuku is one of the pilot schemes involved in the methodology development. Therefore, the original RAP framework was modified and adjusted during the implementation. Based on the results generated through a number of pilot schemes, the first version of the re-vamped and computerized RAP software will be launched in 2021.

and estimation. Each strand – hydrology, institutional management and water service – has its own sets of indicators. Altogether, the three strands consist of over 100 qualitative indicators covering all aspects of management. It is, however, important to mention that RAP is not a simple computational tool converting input data into output file. It combines survey response scales, open-ended questions and close-ended questions. Similar to it, the data sources are diverse, including desk research, historical records, interviews and field observation. Some of the input data are directly analysed through performance indicators computed by pre-defined formulas. On the other hand, RAP also functions as a stocktaking exercise, supporting irrigation expert in a systematic compilation of relevant information. Such input data requirements of the RAP are important to contextualize the performance assessment and provide information for the narrative. Its flexibility and qualitative nature allow the wide-range application, regardless the diverse nature of the irrigation systems.

The methodology implementation is slightly modified as per the objective of the dissertation. However, RAP and other benchmarking protocols normally require their adjustment to the local context, as the diversity of irrigation schemes does not accommodate overly standardized approaches (Gorantiwar and Smout 2005; Gorantiwar 1995; Keller 1986; Rydzewski 1988). Unlike modelling exercises, it is rather a holistic methodology supporting the development projects at formulation phase. Therefore, only a selective number of indicators are used in this dissertation to highlight the facts that are related to the objective of the research. We indicate the applied modification in the further sections to understand the context-driven evolution of the methodology. RAP has two main functions in the research: i./ identifying the relevant management activities in Mubuku and ii./ providing a general overview of the system management and framing the qualitative assessment in the context of Mubuku. The field visit was carried out to conduct the RAP in December 2017, followed by a two-week long desk work to process the data. The performance assessment of the scheme was implemented from limited resources, such as pre-defined financial resources, restricted availability of local human expertise and long-term engagement of local stakeholders. To receive a full picture about the irrigation scheme while taking due account of the resource constraints, the Phase II of Mubuku was selected as pilot area for performance assessment. This area is considered as representative of the lot as a whole. Due to its position and configuration, the identified potentials and limitations in Phase II allow for the characterization of the entire irrigation scheme.

The water balance strand

The chapter involves the hydrological analysis of a selected water year. In its core, it matches the delivered irrigation water with the water requirement of the irrigation scheme, under certain system configurations. The strand has a calculation scheme that takes due account of the potential factors affecting both side of the equation, demand and supply. It calculates the crop water requirement based on the actual cropping pattern, the climatic features, and irrigation practices. The so-called "External indicators" are comprised of a set of relevant indicators appraising the sufficiency of irrigation water. In line with the objectives of the dissertation, the Field Irrigation Efficiency (FIE) indicator is analysed and discussed in the Results chapter to assess the sufficiency of the irrigation water in Mubuku. The FIE is the ratio of net water requirement and supplied irrigation water to the fields at irrigation scheme level. To obtain the net water requirement, the evapotranspiration-based water requirement (ET_c) is calculated at first step (Allen et al. 1998). The ET_c is corrected with the individual irrigation practices (i.e., pre-wetting, paddy filling, etc.) and leaching requirement, which are considered additional water requirements. At last step, this gross water requirement is reduced by the effective precipitation and the regulated deficit strategy, if exists. On the other side of ratio, the water supply is calculated from the irrigation water entering the scheme. Such gross water supply is reduced by the water losses. Water losses derive from the conveyance losses and efficiency of field irrigation methods, which concern both runoff and deep percolation. The Figure 7 gives a schematic overview of the calculation process.

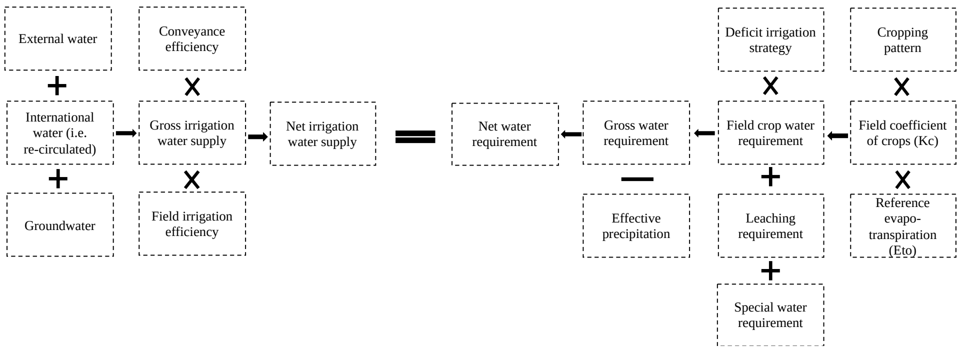

Figure 7: Schematic calculation scheme of the water balance strand (source: modified and abstracted from FAO, 2001: Rapid Appraisal Process (RAP) and Benchmarking. Explanation and Tools)

The indicator calculations require a certain methodology to measure the discharge and water requirement. To achieve highly accurate measurements and estimates, our multidisciplinary research team set up a data acquisition system, involving field observations and the construction of drop structures for discharge monitoring (Salman 2019-b). The discharge monitoring campaign was performed during 2 years to set-up a discharge history and estimate the amount of irrigation water. Prior to the RAP implementation, the crop water requirements of the crops were monitored at each crop development stage throughout the irrigation seasons. (Salman et al. 2019-b; Salman et al. 2020-b). The acquired datasets of both the water requirement and the water supply are the basis of the calculation of FIE[4].

The management strand

The second RAP strand is directly related to the institutional management. The RAP enables the analysis of nested management functions to a certain extent by setting the scope for the appraisals of both governmental authorities and WUAs. This strand acts as a stocktaking exercise, whereas the key functions of the institutions are assessed to describe the main characteristics of management settings. The management survey covers multiple aspects of the institutional operations, including the analysis of the budgetary background, the employees, the functions of the institutions, the effectiveness of the institution, the operational rules and performance. Amongst many indicators, the management strand introduces the main performance indicators of the RAP philosophy, called "Water Delivery Service" indicators. Such indicators are the following: reliability, flexibility, equity and control of flow. They are scored through a 5-point Likert scale, ranging from 0 to 4. RAP applies a guide of the scoring to minimize the biases and subjective evaluation, presented in Table 5 (Burt 2001):

[4] The water balance related RAP results are published by the same authors, and a thorough hydrological analysis of Mubuku irrigation scheme can be found in Bettili, L., Pek, E. and Salman, M. (2019): A decision support system for water resources management: The case study of Mubuku irrigation scheme, Uganda.

Table 5: Scoring plan of Water Delivery Service indicators of RAP (source: Burt 2001)

Indicator	**Scoring plan**
Control of flow	4 – Excellent measurement and control devices, properly operated and recorded. 3 – Reasonable measurement and control devices, average operation. 2 – Useful but poor measurement of volumes and flow rates. 1 – Reasonable measurement of flow rates, but not of volumes. 0 – No measurement of volumes or flows.
Flexibility	4 – Unlimited frequency, rate, and duration, but arranged by users within a few days. 3 – Fixed frequency, rate, or duration, but arranged. 2 – Dictated rotation, but it approximately matches the crop needs. 1 – Rotation deliveries, but on a somewhat uncertain schedule. 0 – No established rules.
Reliability	4 – Water always arrives with the frequency, rate, and duration promised. Volume is known. 3 – Very reliable in rate and duration, but occasionally there are a few days of delay. Volume is known. 2 – Water arrives about when it is needed and in the correct amounts. Volume is unknown. 1 – Volume is unknown, and deliveries are fairly unreliable, but less than 50% of the time. 0 – Unreliable frequency, rate, duration, more than 50% of the time, and volume delivered is unknown.
Equity	4 – All fields throughout the project and within tertiary units receive the same type of water delivery service. 3 – Areas of the project receive the same amounts of water, but within an area the service is somewhat inequitable. 2 – Areas of the project receive somewhat different amounts 4 (unintentionally), but within an area it is equitable. 1 – There are medium inequities both between areas and within areas. 0 – There are differences of more than 50% throughout the project on a fairly widespread basis.

These indicators express the perception of the stakeholders and are not estimated and corrected by in-situ measurements. Under the management strand, the indicators are scored by the management, involving the main authority responsible for the system operation. Both the governmental authority and the WUA were interviewed, and a final score was agreed by the managers during the assessment phased. The achieved scores under the management appraisal indicate the perception of the system performance from the management's perspective.

The water service strand

The water service appraisal is designed as a stocktaking exercise of the system items. The appraisal scheme supports the collection of the characteristics of certain system configuration and provides a qualitative assessment of the operation, the maintenance level and the performance. The assessment is carried out in a sequential manner, each system level providing service to the dependent system level. The assessment of the water service is less structured than the previous two strands. It requires expert observation and an understanding of irrigation system development. The water service strand also helps identify the key operation features. Similar to the management strand, the water service strand results in a number of so-called "Internal indicators", appraising the physical performance from different perspectives. The water service strand re-introduces the four Water Delivery Service indicators with the difference that the indicators should be scored by the farmers. Once the indicators are scored independently by the management and farmers, the results should be matched to identify the discords between the two stakeholder layers. To better align the appraisal to the dissertation, we focused on the Water Delivery Service indicators only from farmers' perspectives and involved more farmers than defined in the original RAP methodology. The interview involves three farmers from each Division: one upstream farmer near the gated intake, one downstream farmer the farthest from the gated intake, one farmer voluntarily joining the exercise. The goal of this protocol alignment is to understand whether farmers receive equally good irrigation service in each section of the irrigation scheme or some of them are discriminated. By its very definition, PIM suggests that each farmer equally benefits from and contributes to the irrigation system. Therefore, it could be theoretically assumed that no discrepancies arise during the scoring exercise. The social reality, however, is found to be entirely different upon the survey results.

The identification of major management activities is discussed in the next chapter, as they directly contribute to the methodology selection. The results of performance assessment are presented in the 5. Results chapter to be part of the qualitative assessment and set the scene for the overall objective of the dissertation.

4.2.2. Data sources and analysis

The data collection is phased into two successive steps: i./ the farmer survey, ii./ the identification of irrigation management measures through RAP methodology. The current chapter is divided into these two steps accordingly. The first section provides a description of the features and overview of farmer survey. This section gives a thorough explanation about the sampling variables used to build a solid ground for the introduction of selected methodologies. The second section contains the critical step of identifying management measures through RAP implementation, based on which farmers can be grouped. It presents a stepwise process of scaling the research of management transfer at farmer level.

Farmer survey

A structured questionnaire is crafted to obtain relevant information about farmers (ANNEX). The sampling involved every famer in the scheme. However, some farmers refused to answer, and others were unavailable. During three months from June 2018 to August 2018, 122 out of 167 farmers completed the survey in total. Each involved farmer responded to both block of farmers survey. One block is closely interrelated to the identified management measures, whereas farmers were requested to indicate those measures, which they regularly pursuit. This block will be introduced in the next section. The other block of the survey registers information related to farmers' characteristics (education, gender, age, land size, produced crops, membership of WUA or extension service, irrigation training attendance, frequent experience of water shortage or waterlogging, frequent experience of failing production, access to information system on production and water use) and farming outcomes (average yield, average revenue, average production cost, average profit). The summary statistics of the characteristics and farming outcomes is displayed in the Table 6.

Table 6: Summary table of farmers characteristics and farming outcomes

	Obs.	**Mean**	**Std. Dev.**	**Min**	**Max**
Education-level (categorical: primary=1, secondary=2, advanced=3, university=4)	122	1.36	0.75	1	4
Gender (binary: male=1, female=0)	122	0.72	0.44	0	1
Number of members of household (continuous)	122	7.97	3.73	0	24
Age (categorical: 15-25=1, 25-35=2, 35-45=3, 45-55=4, above 55=5)	122	4.58	0.72	2	5
Ha of land (categorical: <3,2 ha=0, 3,2 ha=1, >3,2 ha=2)	122	0.93	0.33	0	2

Continuing

Crops produced (categorical: maize=1, rice=2, onion=3)	122	1.27	0.56	1	3
Membership of cooperative/WUA/extension service provider (binary: No=0, Yes=1)	122	1	0	1	1
Attended in irrigation training/course (binary: No=0, Yes=1)	122	0.64	0.47	0	1
Frequent experience of water shortage or waterlogging (binary: No=0, Yes=1)	122	0.39	0.49	0	1
Frequent experience of failing production (binary: No=0, Yes=1)	122	0.48	0.5	0	1
Access to information system on production and water use (binary No=0, Yes=1)	122	0.81	0.39	0	1
Average yield of the crop (continuous: tons per acre)	122	2.04	0.66	1	5
Average revenue of the crop (continuous: 1000 UGX per acre)	122	3 034	737	1 500	5 500
Average production cost of the crop (continuous: 1 000 UGX per acre)	122	1 864	570	800	3 500
Average profit per acre (continuous: 1 000 UGX per acre)	122	1 271	613	0	2 750

According to the registered surveys, farmers' education level is low, most of the farmers have no higher than primary education. Another fact that makes the low education level an even bigger concern is that Mubuku is established as settlement scheme. As a settlement scheme, lands are distributed as means-tested grants. The primary objective of Mubuku settlement scheme is to absorb the rural unemployment, thus preferring families in vulnerable socio-economic situation over families with substantial agricultural experience. Lack of capacity-building and accumulated knowledge, then, leads to poor agricultural performance.

The average number of household members are eight, and most of them are male headed. Although women have equal rights to access lands, the concept of the settlement scheme is to host families, who establish their homes around the agricultural lands. Most of the farms are male-headed, as primary men are responsible for income generation.

Surprisingly, the majority of the farmers are above 45 years, which highlights a relative imbalance amongst cohorts. This is, however, not in line with the national demographic trend that ranks Uganda as one of the youngest populations world-wide. The high rate of older farmers might be important due to two reasons. The first is the outflux of younger generation from agriculture that questions the access to equal benefits of agriculture. Around 66 percent of the in-country migrants move from rural to urban areas, of which 45 percent are aged between 15 and 29 years (FAO 2017). Amongst the underlying issues is the unemployment and underemployment, accounting for 60 percent unemployment rate amongst the youth. National Economic Policy Research Centre (2013) reported that 42 percent of the youth is a manager of its own land compared to the 77 percent of the prime age and 79 percent of the elderly. Moreover, as little as 19 percent of the young farmers have exclusive ownership of the land, while the rest is under customary tenure system (Ahaibwe 2013). The National Strategy for Youth Employment in Agriculture (2017) defined the reasons of youth deserting rural areas and quitting agriculture sector

(National Strategy for Youth Employment in Agriculture 2017). According to it, youth are deprived of critical assets, such as land, financing opportunities and technical expertise. The second is the distortion in land tenure, as ownership is transferred primarily through inheritance in Uganda (International Institute for Environment and Development 2017). However, the modes of inheritance are largely shaped by traditions, favouring only the male heirs (The Gender Strategy for National Land Policy Implementation of Uganda 2018).

As the governmental leasing condition allows one plot of land – equal to 3.2 ha – to each farmer, most of the farmers have an identical land size. However, some families managed to buy in and increased their land size to the double. Larger farms can operate on the basis of economies of scale. As farmers rarely cultivate cash crops and their market power is limited, the increased land size can facilitate the access to transportation and reach-out to larger markets. However, it can be readily accepted that farmers currently transitioning into commercial farming yet require support in stabilizing their market position.

Corresponding to the result of cropping pattern survey, most of the farmers produce maize (N=72). The Government incentivizes farmers to participate in the maize programme through provision of new varieties, the extension service, training, post-harvest services and other activities. The governmental support is not the only reason of the maize production tough. The climatic condition, the high yield potential and the role of maize in household food security are all in favour of the maize production.

As the Cooperative incorporates multiple services related to technical assistance, irrigation service, post-harvest services, heavy-machine yard, etc., all farmers are requested to be a member of the Cooperative. Being active member assumes that farmers are engaged in the irrigation management. However, an in-depth analysis of the Cooperative's structure is required to understand how strongly farmers are entrenched in management.

Although extension service related to the maize production is provided to farmers, irrigation trainings are not frequent and not all farmers have access to participate. The lack of the sufficient knowledge about irrigation is the deep-rooted cause of the poor irrigation efficiency and the massive over-supply. Although the WUA employs site engineers to supervise the system operation, farmers are still requested to take the responsibilities. This co-joint management setting is defined in the agreement between the WUA and farmers.

The favourable production condition, abundant availability of water, fertile soils, access to agrochemicals and quality seeds enable the productivity growth. Yet almost half of the farmers experience a frequently yield failure, and 40 percent of them a water shortage/waterlogging that can be attributed to the lack of agricultural experience and education.

Although most of the farmers have access to an information system on production and water use, these systems are mostly limited to maize-related governmental programmes. Diversified information systems, such as access to flood and drought early-warning, weather forecast, market price information or pest information are not yet implemented in the irrigation scheme.

The standard deviations between minimum and maximum revenue, cost and profitability are high. While some farmers do not produce any profit, the maximum achievable profit per acre per season is 2 750 thousand UGX (equal to 749 USD, 1 USD = 3 751 UGX in 2018). The diverse practices without well-established optimal practices put some of the farmers well behind the others.

Farmers participatory index – the indicator of management measures

The RAP provides an analysis of the irrigation system through a multilevel management, whereas each level provides a service to the next level, from the water source to final deliveries. Such feature of RAP is brought forward, and the methodology is used to decompose the management activities and delineate the actual management measures taken by farmers. As iterated previously, no two irrigation schemes are exactly alike, consequently the management arrangements and modalities differ from one irrigation scheme to another. The definitions of management activities in Mubuku are based on the observations of the expert group via RAP protocol. Contextualization of the methodology starts with the revision of RAP questionnaire to highlight those parts that fit into the circumstances of the irrigation system. A review of the RAP methodology by Salman and Pek (2019) concludes that "Instead of traditional analysis, social (PIM) and institutional management together must be considered: the case studies proved that farmers' contribution – both in monetary and in-kind terms – is at the core of irrigation management, and the relatively good performance of a scheme at headworks can be completely undermined at farmer-operated levels". Therefore, the RAP methodology in Mubuku adapted to the context of management transfer and focused on the interaction between WUA and farmers.

Table 7 introduces the relevant parts of RAP, which guides the identification of a set of management activities in Mubuku. The 14 defined management activities are divided into three main responsibility domains: management, financing and maintenance (Salman, 1997). As explained in the command area introduction, the irrigation system suffers from performance flaws coming from both design and O&M issues. However, a design modification does not fall under the scheme management but belongs to the strategic development. Therefore, the current research does not discuss re-engineering activities. While conducting such research, it is important to take due account of farmers' ability to purse the given activity. Any activity, which can be transferred only virtually, is out of the scope of PIM. Consequently, our selected measures are equally accessible to every farmer, thus ensuring a level playing field in adopting PIM.

Table 7: Identified management activities and their reference in RAP

Relevant RAP section	**Irrigation management domain**	**Identified management activities**
'Water Balance'; 'Service and Social Order'; 'Budget, Employees, WUAs'; 'Operation of the second/third level canal'	Management (including operation)	Water discharge measurement
		Visiting other schemes
		Cooperation with other farmers to re-distribute water
		Regular participation in irrigation training
		Other water-management techniques
		Attending meeting in irrigation turn planning
		Regular participation in extension service related to irrigation practices
		Adjustment of water supply to observed crop demand

Continuing

'General condition for the second/third level canal'; 'Operation of the second/third level canal'; 'Budget, Employees, WUAs'	Maintenance	Weeding, bushing, profiling tertiary and quaternary canals
		Regular manual work on the irrigation infrastructure
		Consultation with WUA officers about maintenance
		Private investment on the irrigation infrastructure
'Budget, Employees, WUAs'	Financing	Contribution (in-kind or cash) to canal maintenance
		Regular payment of water fee

In order to measure the degree of farmers' participation in irrigation management, farmers were asked to indicate those management measures, which they regularly pursue. This important step helps re-define PIM in Mubuku, whereas co-management does not clearly distinguish the transferred responsibilities. The definition of farmers participatory index (FPI) is constructed from these management measures. After the identification and categorization of the activities, weight is assigned to each measure. Such weight corresponds to its potential positive effect on system performance. In order to set the right weight and align them to the objective of the research, a literature review is undertaken. The guiding concept of the weighting process is to rank the activities as per their contribution to the key indicators of performance in farmer-managed irrigation systems. As Hussain and Hanjra (2004) defined in their landmark study on irrigation and poverty alleviation: "The decentralization of authority, and user participation in irrigation management, may improve productivity, efficiency and equity" (Hussain and Hanjra 2004). As management activities must be identified considering the individual features of the irrigation system, the weight assignment must be adapted to the particularities of the system. The process follows the recommendations of the relevant publications and protocols, as well as concerns the local particularities. In general, the more the activity moves away from the direct and cross-cutting impact on the performance, the lower weight is assigned. The Figure 8 displays the composed hierarchy of the identified management activities.

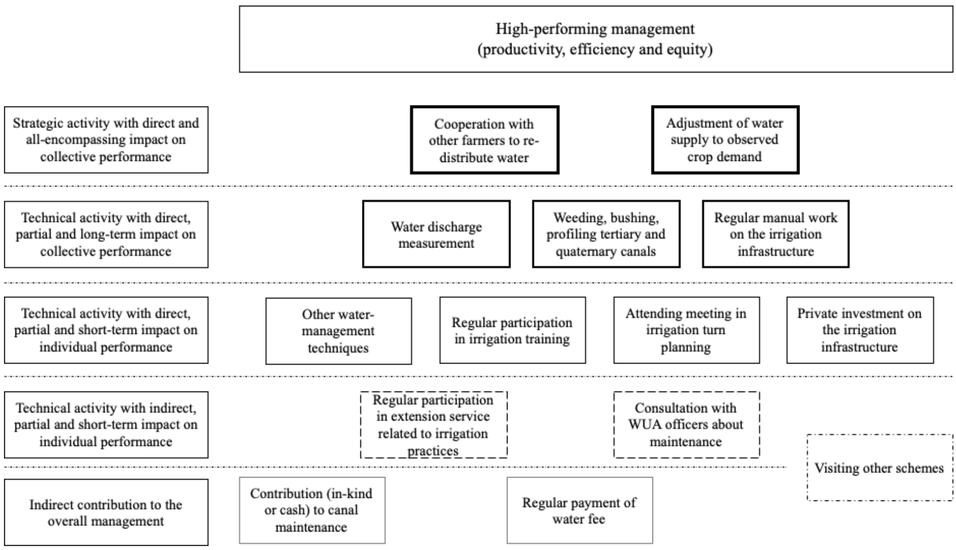

Figure 8: Hierarchy of the management activities based on their impact on performance

The activities with highest weights are those related to the equal and sustainable distribution of water resources, namely the adjustment of water supply to observed crop demand and the cooperation with other farmers to re-distribute water. The impact of these activities rests on their ability to provide a baseline for performance assessment and have a direct and all-encompassing impact on key indicators (productivity, efficiency and equity). They, also, set the strategy of the irrigation management at micro-level through directing stakeholders towards the key objectives of high-performing management. The balancing approach of adjusting supply to demand is the core concept of water and irrigation efficiency related studies at global and micro level and accepted by international development and research organizations (Perry 2007; FAO 2012-a; Hussain et al. 2011; Jensen 2007; Reinders 2016; Ward and Pulido-Velazquez 2008; Fanadzo et al 2010; Kadyampakeni et al. 2014). As Burt et al. (1997) defines "At the heart of any consideration of irrigation performance is an irrigation-water balance and determination of the fate of various fractions of the total irrigation water applied…" (Burt et al. 1997). In general, the irrigation to deliver the water amount required to meet the crop water requirement is a simple and clearly defined objective. (Murray-Rust and Snellen 1993; FAO 1989; FAO 2012-b; FAO 2002; Rai et al. 2017; Perry et al. 2009; English et al. 2002). The balance between input and output contributes to the maximization of productivity both in physical (yield) and resource use efficiency (water productivity) terms. It also directly responds to the need of end-users. In conclusion, balance of supply and demand at system level is the baseline of any performance evaluation regardless the setting of the institutional management. Regarding the activity on cooperation, the guiding principle for water distribution is the equity and need (Roa-Garcia 2014; Syme and Nancarrow 1996; Rogers et al. 2002). At global level, attempts are made to create water allocation schemes consistent with efficiency and equity objectives, thus supporting the overall concept of IWRM (Dinar et al. 1997). The overall objective of water allocation is to meet the needs while maximizing the benefits of the unit of water (IWMI 1999; FAO 2004-a; Babel et al. 2005; Harou et al. 2009). The allocation, however, must be scaled at farmer level to fulfil the overall goals at micro level. As Dinar et al. (1997) defines "the major advantage of user allocation is the potential flexibility to adapt water delivery patterns to meet local needs" (Dinar et al. 1997). This concept has particular merit in the context of farmer-managed irrigation systems. If farmers have the means of cooperation to re-distribute water amongst themselves, the overall objectives of creating equity and responding to actual needs can be achieved. This can also mitigate the adverse impacts of rigid management rules such as rotational irrigation schedule in Mubuku. Such cooperation on water distribution, then, is a proxy of equal, efficient and demand-driven irrigation management and gives the opportunity to alleviate the inherent constraints of the management issues. In summary, the two activities set the strategic principles of irrigation management to guide and aggregate the objectives of the other management activities.

The second set of activities includes the works contributing to the development of the infrastructure to increase the efficiency at system level. These activities are the water discharge measurement; weeding, bushing, profiling of tertiary and quaternary canals; and regular manual work on the irrigation infrastructure. This set is the combination of physical works contributing to the improvement of conditions, thus amplifying the impact of the strategic activities. They have long-term and collective effect on the overall physical performance of the system. However, they alone do not provide a baseline for irrigation performance, and they are considered technical activities that have direct contribution to individual performance indicators. Such widely used performance indicators are, for example, the conveyance efficiency, application efficiency or uniformity (FAO 1985; FAO 1989; Machibya et al. 2004; Bos and Nugteren 1990; Rijo and Pereira 1987). Their implementation is also conditional, as they depend on the status of the system, available resources and technical expertise.

Similar to the previous set, the third set of activities can increase the impact of the first set of activities, but their contribution has short-term impact, or their benefits are accounted for the performance at farm-level or micro-system level infrastructure. Their contribution to the key performance indicators largely depends on farmers' ability to implement the activity correctly and collectively. The two 'soft' activities are related to the dedicated capacity-building regarding irrigation and the contribution to the irrigation planning in WUA meetings (Yin et al. 2016; Chen et al. 2009). Unless farmers and the WUA are not obliged to turn the improved capacities and planning mechanism into action, they rather represent a patchy management process. The 'hard' activities include the other water-management techniques (e.g. in-situ water harvesting) and private investment on the irrigation infrastructure. Private and on-farm water management has the ability to increase the performance of irrigation system, but only in a segment of the irrigation system. In conclusion, their effects do not span across the system and have only partial benefits.

The fourth set of activities have only indirect impact on the performance indicators, as they act through the grassroots level organizations (extension service and WUA). As extension service provides agronomic services to support the productivity, its curriculum incorporates only the on-farm level irrigation, targeting the soil water retention. Accordingly, the contribution to the system-level performance is only partial and indirect. The consultation with WUA about maintenance has also only indirect impact, because it depends on the ability and willingness of WUA to carry-out the work. However, it is not likely that farmers can enforce the implementation of such activity, in particular if WUA is not adequately resourced. The activity of visiting other scheme is in support of technology transfer. However, the transfer can be considered either at farm level, whereas farmers exchange knowledge on farming practices or at system level, which is greatly limited by the similarity of resource endowment.

Finally, the bottom activities are the support of the WUA to maintain its mandate. The contribution to canal maintenance and regular payment of water fee are interchangeable activities financing the WUA responsibilities agreed by the members and beneficiaries. The low weight assigned to monetary and in-kind payment is not meant to undermine the importance of irrigation fees. However, there is a long-standing debate on irrigation fees without universally accepted solution (FAO 2004-b; Tsur and Dinar 1997; Perry 2001; Easter and Liu 2005). Red Bell et al. defines this problem statement as following: "Conventional wisdom in many agricultural systems across the world suggests that farmers cannot, will not, or should not pay the full costs associated with surface water delivery" (Red Bell et al. 2016). In the context of the dissertation, the irrigation fees can be considered neither direct nor targeted instruments. As the WUA is financed by both the farmers and the state, and farmers pay flat fee, the real-term contribution to the performance cannot be properly estimated. In other words, there is no institutionalized agreement on how payment can be enforced, and what are the consequences of non-compliance.

Such weighting processes involuntarily carry a certain degree of arbitrariness, as management settings vary widely across different irrigation schemes. Therefore, the weights were also validated by an expert pool during the field mission in June 2018 to align the theoretical framework to the context of Mubuku and eliminate biasness. The 14 measures were measured in dichotomous scale in the second block of the farmers survey. Farmers achieving higher score than FPI=0.5 are grouped into "participating group", and others into "non-participating" group. This approach is selected to maintain a well-balanced group. After the computation of FPI, participating group accounts 60 farmers and non-participating has 62 farmers. In the Table 8, the left columns display the main management dimensions and the management measures, the middle column indicates the assigned weight, and the right column present the aggregated scores of participating, non-participating and all farmers. The rightmost column includes the result of the non-parametric Mann-Whitney test to identify the differences in pursued activities amongst groups.

Table 8: Comparison of participating and non-participating farmer groups by FPI

Irrigation management domain	**Identified management activities**	**Standardized weights**	**Participating farmers**	**Non-participating farmers**	**All farmers**	**Mann-Whitney test (prob>|z|)**
Management (including operation)	Water discharge measurement	0.1	0.05	0.0016	0.0033	0.29
	Visiting other schemes	0.02	0.008	0.0074	0.0075	0.88
	Cooperation with other farmers to re-distribute water	0.2	0.193	0.1613	0.1170	0.05*
	Regular participation in irrigation training	0.05	0.039	0.0331	0.0361	0.00***
	Other water-management techniques	0.05	0.003	0.000	0.0016	0.03*
	Attending meeting in irrigation turn planning	0.05	0.039	0.0331	0.0361	0.13
	Regular participation in extension service related to irrigation practices	0.03	0.020	0.0097	0.0145	0.00***

	Adjustment of water supply to observed crop demand	0.2	0.127	0.0065	0.0656	0.00***
Maintenance	Weeding, bushing, profiling tertiary and quaternary canals	0.1	0.090	0.0677	0.0787	0.00**
	Regular manual work on the irrigation infrastructure	0.1	0.077	0.0177	0.0467	0.00***
	Consultation with WUA officers about maintenance	0.03	0.022	0.0121	0.0170	0.00***
	Private investment on the irrigation infrastructure	0.05	0.028	0.0258	0.0266	0.70
Financing	Contribution (in-kind or cash) to canal maintenance	0.01	0.005	0.0021	0.0035	0.00***
	Regular payment of water fee	0.01	0.005	0.0027	0.0037	0.02*

The major differences between the two groups are found regarding the following activities: i./regular participation in irrigation training, ii./ regular participation in extension service, iii./ adjustment of water supply to observed crop demand, iv./ regular manual work on the irrigation infrastructure v./ contribution to canal maintenance, and vi./ consultation with WUA officers about maintenance.

The comparison is particularly interesting in the case of financing-related management aspect. None of the groups achieve 100 percent fee collection rate and provide an additional contribution to the scheme management. Although the concept of WUA builds on the self-financing and farmers' contribution, the Mubuku case proves that farmers often remain reluctant to pay for irrigation services.

Regarding the two activities having the highest weight, namely the cooperation with other farmers to redistribute water and the adjustment of water supply to crop demand, participating farmers have a stronger engagement. Considering the discussed importance of balancing approach, this measure plays major role in achieving a good irrigation service. A better strategy of management transfer should consider the improvement of farmers' understanding on the benefits in the future.

Through Mubuku case study, we show that management transfer is not a linear process, where farmers have identical preferences and interest that drive towards a coherent policy implementation. As Venot and Clement (2020) defines "Attempts at institution-building overlook the social relationships through which participation, authority, legitimacy and accountability are continuously negotiated among multiple actors" (Venot and Clement 2020; Cornwall and Brock 2005; Blaikie 2006). The majority of the existing literature does not analyse farmers' engagement in such depth. Based on their assumptions, farmers in transferred irrigation schemes are considered as a homogenous group having the same role and engagement in management. In reality, and also proved by the FPI results, farmer communities are diverse and complex in terms of the attitude and the motivation. Centring farmers in the heart of PIM, then, gives a realistic overview of their real contribution to the management. The computed FPI is used in the further chapters as a participation variable, expressing the farmers engagement in PIM. As a result, FPI is the proxy of farmers' active role in PIM. This critical step of introducing FPI contributes to the first novelty of the research of investigation of the PIM directly through farmers' measured participation. The research, then, directly tackles the defined concerns of researchers about the potential influence of farmers' diversity and asymmetric involvement on management transfer.

4.2.3. Empirical methods and specifications

This chapter contains three sub-chapters discussing the empirical methods and their specification in the dissertation. The applied research methodologies are introduced as they relate to the specific research objectives, namely i./ measuring farmers' motivation pattern in participatory irrigation management, ii./ clustering farmers by participation in irrigation management, iii./ estimating the effect of participatory irrigation management on farming outcomes. The sub-sections of the current chapter are structured to introduce the variables applied in the particular research step, describe the research methodology and justify the reason for methodology selection.

Empirical methods to measure farmers' motivation

In first step, farmers' motivation to participate in irrigation management is investigated. The following variables are used as explanatory variables: education, gender, age, produced crops, number of household members and land size. The summary statistics of the selected variables can be found in Table 6 in chapter 4.2.2. We select these variables because they are predictable and less likely to change by external factors. The rest of the variables, such as experience of frequent water shortage or waterlogging might be one-time event that affect farmers' perception. For example, a farmer failing to obtain reasonable yield twice in a row might report it as a frequent event. However, it cannot be assumed that the farmer permanently fails to produce yield. Therefore, only those characteristics are included in the estimation, which are consistent in time and are not likely to be easily influenced by other factors. The causal effect of explanatory variable is measured on three binary outcome variables: farmers' participatory index (FPI), attendance in irrigation training and access to information. These variables are considered the proxies of the participation. Beyond FPI, we assume that the attendance in irrigation training and the access to information are influenced by farmers' characteristics. It is important to note here that attendance in irrigation training differs from the FPI management measure of regular participation in irrigation training. While this latter indicates a more regular activity carried out by the WUA or extension service and reflects on day-to-day work, attendance in irrigation training refers to one-time and in-depth capacity-building provided by development projects. The major difference between the two is that the irrigation training as management measure facilitates the daily work and operation of the irrigation system, while irrigation training as capacity-building programme aims at empowering farmers to understand engineering and agronomic aspects of irrigation.

Alternative methods of semi-parametric and semi-nonparametric estimation for binary-choice models are proposed to identify driving factors of participation. The reason of method selection is its robustness and higher explanatory power when the error distribution of the explanatory variables is unknown. In contrary, parametric methods assume that the variables have known underlying error distributions (normal, poisson etc.). If the distribution is not specified, the estimator becomes inconsistent, thus reducing explanatory power of the model. Given the number of nominal and ordinal explanatory variables, semi-nonparametric (SNP) of Gallant and Nyhcka (1987) and semiparametric maximum likelihood approach (SML) of Klein and Spady (1993) are applied (Gallant and Nyhcka, 1987; Klein and Spady, 1993). Semiparametric models combine the parametric component of data processing with nonparametric restrictions. In the following paragraphs, the specifications of the models are summarized. The model description recaps the work of De Luca (2008), who published his work on prefixed SNP and SML codes in STATA software. STATA was used all over the research, so the model specification of De Luca provides sufficient information (De Luca, 2008).

SNP model by Gallant and Nyhcka suggests nesting the probit while allowing nonnormal distribution, thus combining both parametric and non-parametric components in the model (Gabler et al. 1993). SNP approximates the density of choice by expansion in Hermite functions, described as the following,

$$h * (\varepsilon_1, \varepsilon_2) = \frac{1}{\psi M} \alpha_M^2(\varepsilon_1, \varepsilon_2))^2 \phi(\varepsilon_1)\phi(\varepsilon_2)$$

Where ε_{n} is the variable, $\mathrm{h}(\varepsilon) \subset \mathrm{HM}$, α_M is a polynomial order of M, ψM is a normalization factor, and Φ is the distribution function with mean 0 and covariance matrix Σ (El-Osta 2017). As Hermite polynomials are orthogonal polynomial sequence for Gaussian distribution, they form a basis for the estimation of normal distribution. Log-likelihood function is then maximized while replacing the unknown distribution by the approximations. According to the proposal of De Luca (2008), zero-mean condition and unit variance of latent regression errors is difficult in binary modelling (De Luca, 2008). The author proposes to follow the approach of Melenberg and van Soest (1996) and set two intercept coefficients, $\propto_1$ and $\propto_2$ to their parametric estimates (Melenberg and van Soest, 1996). Based on this restriction, joint distribution function F is approximated as the following,

$$F(\varepsilon_1, \varepsilon_2) = \Phi(\varepsilon_{1_1})\Phi(\varepsilon_{1_2}) + \frac{1}{\psi R} A_1(\varepsilon_{1_1}, \varepsilon_{1_2})\phi(\varepsilon_{1_1})\phi(\varepsilon_{1_2})$$

$$- \frac{1}{\psi R} A_2(\varepsilon_{1_2})\Phi(\varepsilon_{1_1})\phi(\varepsilon_{1_2}) \; - \frac{1}{\psi R} A_3(\varepsilon_{1_1})\phi(\varepsilon_{1_1})\Phi(\varepsilon_{1_2})$$

Furthermore, marginal densities are integrated in the marginal distribution functions:

$$F_1^*(\varepsilon_{1_1}) = \Phi(\varepsilon_{1_1}) - \frac{1}{\psi R} A_3 * (\varepsilon_{1_1})\phi(\varepsilon_{1_1})$$

$$F_2^*(\varepsilon_{1_2}) = \Phi(\varepsilon_{1_2}) - \frac{1}{\psi R} A_2 * (\varepsilon_{1_2})\phi(\varepsilon_{1_2})$$

where, ψR is the normalized error distribution, and approximations imply that bivariate probit model is only nested in SNP model if the correlation coefficient is equal to zero. Unknown distribution functions F is replaced by approximations of F^*.

SML estimation method involves maximizing pseudo-log-likelihood function, where unknown probability is approximated by nonparametric kernel estimator (Klein and Spady, 1993), as following,

$$\widehat{g_{1v}}(v_i, h_n) = \{(n-1)h_n\}^{-1} \sum_{j \neq i}^{n} y_j K(\frac{v_i - v_j}{h_n})$$

where, $v_i = v\left(K_{i,\delta}\right), K(.)$ is the kernel function and h_n is a bandwidth parameter. SML estimator maximizes the pseudo-log-likelihood function with a nonparametric estimator:

$$\hat{h}(\delta) = \frac{\widehat{g_{1v}}(v_i, h_n)}{\widehat{g_{1v}}(v_i, h_n) + \widehat{g_{0v}}(v_i, h_n)}$$

For binary models, the nonparametric estimator of the conditional probability is $\pi_{1|1}(\theta_1, \theta_2\ ) = \Pr(Y_2 = 1|Y_1 = 1, X_1\, X_2)$. By replacing bias-reducing kernels with Gaussian kernels, the probability is estimated by,

$$\widehat{\pi_{1|1}}(\delta) = \frac{\widehat{g_{1v|1}}(v, h_{n1})}{\widehat{g_{1v|1}}(v, h_{n1}) + \widehat{g_{0v|1}}(v, h_{n1})}$$

and log-likelihood function is maximized to obtain SML estimator δ.

In conclusion SNP and SML models are nonlinear models that can be transformed into linear in their parameters. As mixed type of explanatory variables and binary outcome variables are used in the research, the alternative nonparametric methods are applied simultaneously to avoid biased results and reinforce the outcomes.

Empirical methods to clustering farmers based on their participation

In order to identify the similarities in farmers' participation pattern, a data clustering is performed. The research groups farmers as per their decision on participating in irrigation management, applying the three participation variables defined in the previous sub-section (irrigation training attendance, access to information, FPI). It also examines whether the associated observed characteristics are similar or different from one group to another. Regarding the characteristics, the analysis involves the same variables described in the previous section of 'Empirical methods to measure farmers' motivation and summarized in Table 6 of chapter 4.2.2., but it applies two further explanatory variables, namely the profit and revenue. Such further variables are introduced to characterize farmers' livelihood by participation. Although the variables of yield and production cost are also related to the livelihood, they are not analysed under the current research question. The yield variable cannot be applied in the current case, since yield cannot be compared across farmers producing different crops. Furthermore, the production cost is omitted from the analysis, since the profit is calculated from the difference of production revenue and production cost. Applying production cost would result in redundancy and direct correlation between two variables.

The clustering methods are used to evaluate similarity by distance measures. Given a dataset $Z = \{z_1, z_2, z_3 \dots . z_p, \dots . , z_n\}$, where $z_p$is the pattern in N_{d-} dimensional feature space, N_p is the number of the pattern, and Z is partitioned into clusters. Clustering must meet the conditions of i./ having each pattern assigned to a cluster, ii./ having at least one pattern per each cluster, iii./ having each pattern to only one cluster (Omran et al. 2007). Euclidean distance is the most frequently used formula to measure distance by

$$d(p,q) = \sqrt{\sum_{i=1}^{n}(q_i - p_i)^2}$$

where p and q are the distant point, q_i and p_i are Euclidean vectors in n space (Elmore and Richman 2001).

To understand whether the obtained clusters are significantly different on any of the variables, Kruskal-Wallis test is applied. Kruskal-Wallis is a non-parametric test used to determine whether more than two independent groups are different on some variables (Chan and Walmsley 1997). Kruskal-Wallis is the alternative of ANOVA for the cases when the assumption of normality is not met. The assumption of the Kruskal-Wallis is the following:

$$X_{ij} = \mu_i + e_{ij}$$

whereas X is the observation j in group i, μ_i is the mean or expected response of data in the treatment and e_{ij} are independent observation from some common distribution. The null hypothesis (H_0) is that all means are identical. The test statistic is

$$K = \frac{12}{n(n+1)} \sum_{i=1}^{a} n_i (\overline{R}_\iota - \frac{n+1}{2})^2$$

Whereas K is the Kruskal-Wallis test that approximates to x^2 distribution with k-1 degrees of freedom, n is the total number of observation, $\bar{R}$ is the sum of ranks of observations in the i sample, and n_i is the number of observations in group i (Ostertagova and Ostertag 2014).

The clustering is complemented with canonical discrimination function (CDF). CDF is defined as linear combination that separates the mean vectors of groups. Standardized coefficient is calculated to provide information on joint contribution of variables to CDF (Rencher and Christensen 2012). Rencher and Christensen (2012) discusses that through canonical discrimination, $\bar{x}_n$ mean vector of the group in S matrix is replaced by $y = a'x$, and the ratio is maximized by Fisher's (1936) linear discrimination function as the following:

$$\sum (\bar{y}_1 - \bar{y}_2)^2 / (y_{ij} - \bar{y}_i)^2 = a'Ba/a'Wa$$

Where B and W are the usual of matrices' sum of squares and cross-production from multivariate analysis of variance.

The method is selected to identify the profiles of farmers groups by the participation in irrigation management. Clustering is robust method to find similarities in observed characteristics and distinguish groups by dissimilarities.

Empirical methods to estimate the effect of participation on farming outputs

As per the research objective, the effect of participatory irrigation management is measured on three farming outcomes: farm revenue, profitability and productivity. By selecting two profitability and one productivity related impact indicators, the research has positive contribution in improving the farmers-centred impact assessments of management transfer and directly responds to the identified literature gap regarding the measurement of farmers' benefits. Alternative research methods are applied to estimate how these outcomes vary according to the binary treatment of farmers' participation in irrigation management. As discussed in the chapter 4.2.2. Data source and analysis, Farmers Participatory Index (FPI) is computed to pool farmers into two groups based on their degree of participation in management: participating and non-participating group. Concurrent comparison of participating and non-participating groups while providing the same accessibility of participation activities eliminates the entailed uncertainties of the changing production conditions such as weather, soil, water availability, production technology, etc. The FPI distinguishes farmers into two groups: participating and non-participating groups. According to the research methodology, these two groups correspond to the treated and control groups respectively. The groups are well-balanced, involving 60 farmers in the treated and 62 farmers in the control group. In the model specifications, the i./ FPI is the treatment variable, ii./ the farmers characteristics, alternatively observable characteristics are the treatment independents, and iii./ farming outcomes are the outcome variables:

- The treatment independents are used to pair farmers based on their similarities in observable characteristics. The following treatment independents are included in the model: education, gender, age, household number, attendance in irrigation training, frequent experience of water shortage or waterlogging, frequent experience of failing production and access to information system. These variables provide sufficient information to identify farmers with common characteristics and perform the matching.
- The systematic review proved that the greater part of impact assessments uses performance indicators, which have only indirect impact on farmers' livelihood. Farmers who do not realize direct gains contributing to their socio-economic conditions might become hesitant to substantially engage in management. On contrary, well-demonstrated physical and monetary gains can prompt farmers to adopt participatory management. Therefore, direct farming outcomes, namely

revenue, profit and productivity are found to be appropriate indicators. Profit and productivity are calculated from recorded crop yield, production cost per unit and production revenue per unit. Profit is considered the most suitable outcome variable when considering agriculture in pro-poor context. Unlike revenue, profit is the residual income of farmers that can be spend for livelihood expenditures. The difficulty with the financial variables, and perhaps the reason of its frequent omission from research designs is their complexity and market-related uncertainties. As the cost-benefit analysis shows, upward and downward market trends largely influence the profitability of crops other than maize. The further complication is that no market information can be obtained from Mubuku, hence, farmers are limited to local market. In order to overcome the uncertainties of financial indicators, productivity variable is introduced to complement the impact assessment. The productivity variable is, however, only applied for maize-producing farmers (N=95) to ensure the comparability in crop yield production. The yield is measured as dry biomass production of maize after healing and drying. As the maize programme provides trigger price and equal access to production facilities, the maize production is independent from market uncertainties.

Two-sample non-parametric test is performed to assess the differences in variables between the two groups. The results are displayed in the Table 9.

Table 9: Difference in means of treatment independents[5]

	Total	Control	Treatment	Difference	P-value
Treatment independents					
Education level	1.36	1.19	1.53	-0.34	0.01*
Gender	0.73	0.73	0.73	-0.00	0.92
Age	4.58	4.60	4.57	0.03	0.82
Number of household members	7.97	7.34	8.63	-1.29	0.05
Irrigation training attendance	0.65	0.55	0.75	-0.20	0.02*
Frequent experience of water shortage or waterlogging	0.39	0.43	0.35	0.08	0.34
Frequent experience of failing production	0.48	0.50	0.47	0.09	0.71
Access to information system	0.81	0.79	0.83	-0.04	0.55

continuing

[5] Note on significance levels: * corresponds to $p \leq 0.10$, ** corresponds to $p \leq 0.05$, *** corresponds to $p \leq 0.001$.

Outcome variables					
Revenue in thousand UGX	3 134	2 901	3 375	-474	0.00***
Profit in thousand UGX	1 270	1 047	1 501	-453	0.00***
Productivity in tons/ha	2.04	1.90	2.19	-0.29	0.01*

The major difference between the groups are the education level and irrigation training, while the gender and age variables are well-balanced between the groups. It is important to recognize that both groups experience frequent water shortage and waterlogging. The other striking issue is the rate of farmers experiencing frequent production failure. As most of the farmers have only single-source outcome from agriculture, production failure is consequential to livelihood. The differences of outcome variables between treated and control groups are significant, whereas participating farmers reach higher revenue, profit and yield. Given the facts that revenue and profit are recorded in thousand UGX per acre per season and farmers produce in double-cropping, the difference is even higher when calculating the average farm size per farmer (3.4 hectare) in annual step.

The following four alternative econometric methods are used to estimate the average treatment effect (ATE) of PIM in the order of degree of rigor: difference in means, ordinary least square, propensity score matching (PSM) and entropy balancing. Advantage of quasi-experimental method lies in the fact that it does not require randomized groups and allows retrospective analysis of adopting PIM. In the current research, quasi-experimental design with control groups can be considered high-rigor when compared to experimental design (Schweizer et al 2017).

Difference in means is used as naive method to compare the means of farming outcomes (farm revenue, profitability and productivity) between treatment and control groups as the following:

$$t = \frac{\overline{X_A} - \overline{X_B}}{\sqrt{\frac{S_A^2}{n_A} - \frac{S_B^2}{n_B}}}$$

where X_A and X_B are the means of each group, S_A and S_B are the sample standard deviations of the groups, and the n_A and n_B are the population per group. However, the difference in means cannot be considered robust enough, as distinct farmers' characteristics presented in Table 9 can heavily influence the farmers' decision on participation. Measuring the willingness by neglecting the farmers' specific background would lead to statistical biases.

Regression specification is calculated as

$$Y_i = \beta_0, + \beta_1 T_i + \beta_2 X_1 + \varepsilon_I,$$

where Y_i measures various outcomes for individual i. β is the effect of predictor, T_i is the binary indicator of the treatment variable, as participation in management, and X_1 is the vector of characteristics covariates. Similar to difference in means, regression adjustment does not respect the varying characteristics of farmers. Therefore, two more sophisticated and advanced methods are proposed, which enable the consideration of farmers' different background.

The research establishes counterfactual analysis by replicating the characteristic of the participating group for non-participating. In non-experimental research designs, matching techniques are widely used to perform comparison between groups based on the similarity in observed characteristics of each member of the group (Heckman et al. 1999). Based on their characteristics, matching approximates members receiving treatment to members not receiving such treatment. The difference is measured between the matched members and aggregated to estimate the average difference between groups (Cox 1958; Wordofa and Sassi 2018). In other words, measuring the effect of the farmer participation on the outcome variables aims at answering the following question: What would have happened to non-participating farmers if they had participated in management? In order to measure the effect of participation, average treatment effect (ATE) is estimated as following:

$$ATT = E(Y_{i1} - Y_{10}|T = 1)$$

where T is the binary treatment variable, equivalent to the participation in irrigation management, Y_{i1} is the outcome of received treatment, equivale to revenue, profit and yield. Matching methods are suitable for reducing statistical and sampling biases, and imbalance in the characteristics (Wells et al 2013). The treatment effect is estimated as the difference in outcome variables of treated and non-treated farmers matched by their characteristics:

$$\hat{\Delta} match = \frac{1}{N_1} \sum_{i:T_j=1} (Y_i - \sum_{i:T_j=0} W_{i,j} Y_j)$$

where N_1 is the number of treated observations, $W_{i,j}$ is the weight of outcome of matched nontreated observation j with treated observation i. Propensity score of Rosenbaum and Rubin (1938) is widely used matching method to find $\mathrm{E}(Y_{10}|T = 1)$ if only $\mathrm{E}(Y_{10}|T = 0)$ is available (Rosenbaum and Rubin 1938; Becker and Ichino 2020). The effect is estimated by attributing several observable characteristics to treatment units and the prediction of the estimation is used to create a propensity score ranging from 0 to 1. In general, matching requires sufficient number of observable characteristics to obtain accurate results:

$$t(X) = Tr\{D = 1|X\}=\mathrm{E}\{D|X\}$$

where D is the indicators of exposure to treatment, X is multidimensional vector of characteristics. Propensity scores are estimated from standard probit model as below:

$$\mathrm{Tr}\{D_i|X_i\}=\frac{e^{\lambda h(X_i)}}{1+e^{\lambda h(X_i)}}$$

where $h(X_i)$ is the function of covariates with linear and higher order terms. Nearest-neighbour matching is selected to ensure the highest comparability between treated and control units.

Finally, entropy balancing is introduced. The method involves a reweighting process to incorporate a covariate balance into the weight function, thus achieving a balancing property (Erlander 1977; Baborska et al. 2018). Entropy balancing is applied in cases, when the observed characteristics differ between treated and control groups. Weights are assigned to control units, and thus obtain a balance between covariates and minimize loss function by reweighting scheme H(ω). The reweighting scheme reduces the distance between the distribution of estimated control weights and the distribution of the base weights to the most possible extent (Hainmueller, 2011). The balancing function enables similar statistical pre-moments of covariates, such as skewness, mean, variances etc.). Based on moment-independent covariates, the counterfactual mean can be defined as:

$$E\left[Y\widehat{(0)|T} = 1 = \frac{\sum_{(1|T=0)} Y_i \omega_i}{\sum_{(1|T=0)} \omega_i}\right]$$

The adjusted weights eliminate the balance constraints, while keeping the maximum possible information in the reweighted data as following:

$$\min_{\omega 1} H(\omega) = \sum_{(i|T=0)} \omega_i log \frac{\omega_i}{q_i}$$

The key merit of the entropy balancing is the proper approximation of covariate property while keeping estimated weights as close as possible to base weights to minimize the loss of information.

The applied four alternative methods present different estimation approaches and degrees of rigor. Starting from difference to means to entropy balancing, the research goal is to simultaneously estimate the difference in farming outcomes (profit, revenue and yield) between participating and non-participating groups.

5. RESULTS

The current chapter presents the results of our research. The chapter follows the defined structure of the four specific research goals: i./ qualitative assessment of the scheme performance and co-joint management, ii./ measuring the motivation patterns in participatory irrigation management, iii./ clustering farmers on the basis of participation in management and iv./ measuring the treatment effect of participatory management on farming outcomes. The results are discussed per research goals, and the chapter draws together their insights to provide an overall summary of the context and impact of management transfer.

5.1. Qualitative analysis of the co-joint management in Mubuku

This chapter responds to the first research objective of characterizing the co-joint management. Each PIM process has its own specificity based on external and internal factors such as the country's legislations, the institutional background, the structure of agriculture and water sectors or farmers' ability and the willingness to take over responsibility. In first step, we synthetize the results of the RAP implementation to line up the major considerations of performance issues. In second step, we use Ostrom's design principles for self-managing irrigation schemes (Ostrom 1992). This qualitative assessment supports the further research results and provide a general background of their interpretation.

5.1.1. The overview of irrigation system performance

The RAP provides an overall overview of the scheme performance by identifying the root causes of the failures. It consists of a suite of performance indicators described in the chapter 4, of which the field irrigation efficiency and the four indicators of water delivery service (reliability, flexibility, control of flow and equity) are selected to set the scene for the qualitative assessment. The field observations via the Water Service strand of RAP show that Mubuku irrigation system has several design flaws that make the water distribution somewhat cumbersome. The gated offtakes from the main to the secondary, and from the secondary to the tertiary canals are non-functional. Furthermore, Phase II has no exit to discharge excess water at the tail of the main canal, thus conveying the runoff through the field ditches into the drains. The unlined tertiary canals are not properly maintained, thus having often a larger dimension than the secondary canals. The rudimentary system design is only the pre-condition of system management though. Much of the adverse condition can be offset by a well-organized management. Critical in understanding the role of management is its ability to overcome the engineering defects through well organized and cooperative governance.

Field irrigation efficiency – overall water balance

Field irrigation efficiency is defined as the ratio of field water requirement and field water supply, described in the chapter 4. The field irrigation efficiency shows the balance or the opposed imbalance between the required water amount and the supplied irrigation water. 100 percent field irrigation efficiency would assume that the water requirement and the water supply are exactly equalled. Such perfect balance, however, hardly exists in the reality. The larger the deviation from 100 percent, the larger the imbalance. To reach an even more accurate estimation of the field irrigation efficiency, the results are assessed at monthly time step. This is crucial in small-scale irrigation schemes with good amount of annual rainfall, as annual analysis would easily lead to the misperception that off-season water supply compensates the water scarcity in the vegetation period. Likewise, a monthly analysis is necessarily to understand if the annual water supply is evenly distributed according to the water requirement. Figure 9 displays the monthly results of net water supply and net water demand in the two seasons of 2008.

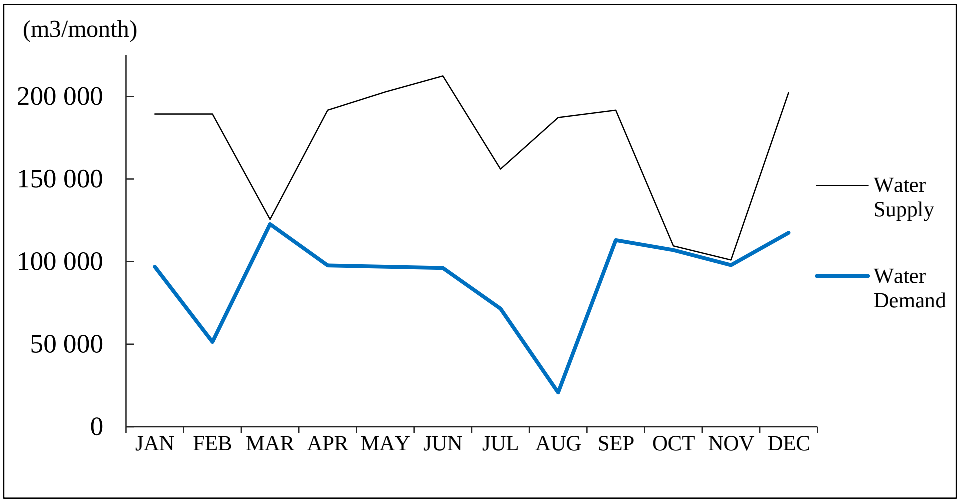

Figure 9: Monthly water balance in Mubuku (source: Bettili, L. et al. (2019): A decision support system for water resources management: The case study of Mubuku irrigation scheme, Uganda. Sustainability. 11(22). 6260.)

The assessment shows large imbalance between water requirement and delivered water on the fields, thus resulting a remarkably low field irrigation efficiency at 14.76 percent. This means that over 80 percent of the withdrawn irrigation water goes to waste. The two main reasons attributed to the massive water supply are related to the design flaws and the poor management. Due to the current engineering design, no contour canal or exit is appended to the system. If farmers downstream from the irrigation scheme want to irrigate, the required volume must be conveyed through Mubuku irrigation system. The other occurring issue is the lack of effective water monitoring and the poor irrigation schedule. This largely ineffective setting has several economic and environmental consequences. Such consequences are the deteriorating infrastructure due to the load exceeding the design capacity, soil erosion, evaporation and percolation losses, water contamination and agrochemical leaching (Salman et al. 2019-b).

Reliability of water services

The water service is scheduled in rotation. Each field is irrigated in every 3-4 days for 4 hours, and two Divisions are open simultaneously. Considering the high discharge of the main canal, farms can be easily irrigated simultaneously. A perfect Reliability would assume that the flow always arrives in time with the expected frequency, rate and duration. The majority of the interviewed farmers agreed that Reliability can be scored at 3, meaning that they encounter slight delays occasionally. It is worth to note that this high score suggests a good understanding of flow volume. In this particular case, the perception of flow volume is supported merely by the observation of water level. Farmers have no data or information about the discharge, but they observe the water level in the canal to compare it to their irrigation history and the level in other canal sections. Besides the positive responders, the two most downstream farmers found that the water service is not reliable and raised their concerns about their inferior position compared to the upstream Division. They frequently experience a low water level that prevents the gravity-fed withdrawal from secondary to tertiary canals. As the canal profiles are fixed, the lower water level necessarily indicates a lower discharge.

Flexibility of water services

The flexibility of distribution is constrained by the rotational schedule that defines fixed irrigation days for each plot. This supply side distribution rule was established long ago with the assumption of timely updating in the beginning of each season. However, no change has been done since it was first established. A perfect Flexibility would assume a continuous flow (unlimited frequency, rate and duration) and unlimited access to water. The rotational irrigation schedule largely influences the farmers' perception, and they all agree that the Flexibility is low, because irrigation is constrained by rotational deliveries and uncertainty in the schedule. It becomes clear that the rigidity of a rotational schedule is one of the main limitations of the system performance. The irrigation schedule is established before the season, and regardless the weather conditions, it is not adjusted. Due to severe inflexibility, farmers are tempted to violate the official schedule and divert water off-schedule. This general phenomenon had been both observed and appealed by downstream farmers, who eventually suffer from insufficient discharge. In this context, the co-management turns into self-management as farmers show no sense of a common responsibility. This is particularly interesting in the light of the FIE results, which clearly highlighted the massive over-supply.

Equity of water distribution

Equity refers to the fair and equal water distribution amongst users, regardless their upstream or downstream positions. The matter of equity has been widely discussed, as equal water distribution proves to have spillover effect on poverty reduction (Lipton, 2007). A perfect Equity in RAP suggests that all fields receive the same type of water delivery service. According to the original guidelines of RAP, the equity should be measured in the most downstream farms due to their exposure to upstream activities. From analytics point of view, it is important, however, to compare the upstream farmers' perception to the downstream farmers. Farmers in upstream divisions, from Division 8 to 11, agreed that they receive equal water service and had no complaint on the distribution. However, the two most downstream farmers in Division 12 raised severe issues in terms of equity. They reported a frequent water shortage due to the unofficial water withdrawal upstream. It can be concluded that the equity within-division and cross-division is acceptable in upstream divisions, while downstream division is put behind the others. In order to confirm the validity of farmers' perception, we visualize the discharge data in the following boxplot. The boxplots in Figure 10 displays the distribution of water discharge during irrigation events (Salman et al., 2019-b).

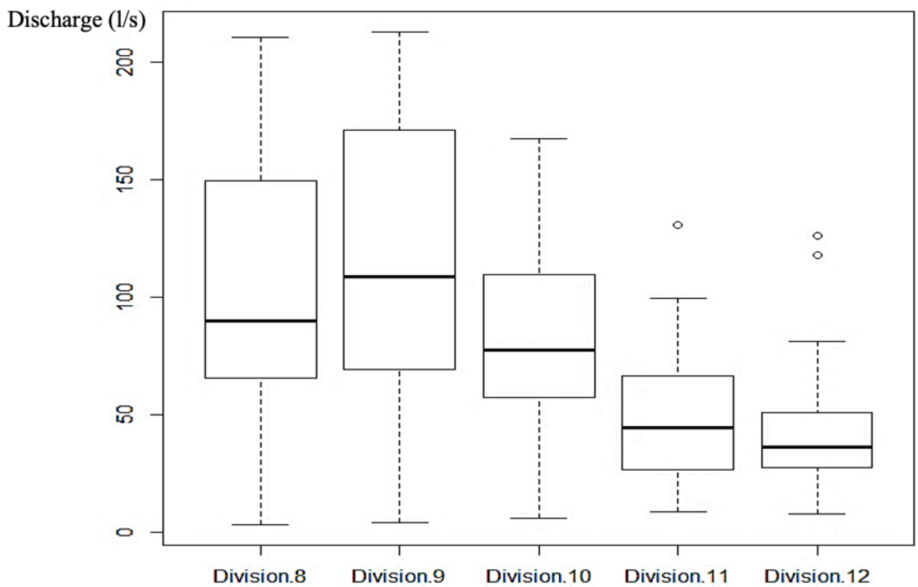

Figure 10: Distribution of the discharge (l/s) amongst the divisions (source: Salman et al. (2020): Policy guide to improve water use efficiency in small-scale agriculture. The case of Burkina Faso, Morocco and Uganda, page 52, Figure 10.)

The analysis shows that farmers towards downstream divisions receive gradually decreasing discharge. This should not be the case as only two secondaries are simultaneously open as per the rotational irrigation schedule. The reason for Division 11 and 12 receiving a considerably lower discharge during irrigation turns is the unofficial withdrawal upstream. Adding to the hurdle, the within-division distribution aggravates the problem in downstream divisions. According to the official schedule, two farms are simultaneously irrigated in the same division, thus leaving the most downstream farm even more vulnerable to “water-stealing” by upstream divisions.

Control of flows

Control of flows refers to the ability to control the discharge. However, the rudimental engineering design of the system does not allow any flow control. The tertiary canals are equipped with distribution boxes and valves to outlet water into ditches. As no meaningful rehabilitation or modernisation has taken place since its establishment, the system has been undergoing a rapid deterioration. The chapter on Field Irrigation efficiency highlighted the issue of an immense over-supply. This overload puts a pressure on the equipment and leads to damages. From engineering point of view, one of the salient system failures is the lack of discharge measurement and the meaningful water control. RAP is based on stakeholder perception though. Therefore, the control of flows is assessed solely by farmers’ perception. All farmers indicated a frequently used but poorly designed control of flow, owing to the beforementioned design issues. Furthermore, the most downstream farmer, receiving the excess flow from other farms, complained about the harmful effects of lack of flow control. Matching farmers’ perception to the Field Irrigation Efficiency indicator shows general misunderstanding of discharge – crop water requirement continuum, as farmers receiving more than sufficient discharge perceive an inadequate water amount.

5.1.2. *Qualitative analysis of the co-joint management in Mubuku*

According to the NWP, farmers are the beneficiaries of irrigation services. In return, they pay annual water fee. However, this full management transfer is still incomplete in Mubuku after 30 years in operation. Therefore, GoU delegates and finances the head of WUA office, while other employees are paid from farmer fees. The participatory management has commonly agreed rules in Mubuku. Beyond the financial costs, farmers are also responsible to operate secondary canals, operate and maintain the tertiary canals and ditches, which entails further contributions such as weeding, canal profiling, unload of sedimentation and any other repair work. As aforementioned, the state controlled WUA is responsible for the operation and maintenance (O&M) of main canal, and the maintenance of secondary canals. One intermediate layer is virtually inserted into the management hierarchy in Mubuku, as farmers at secondary canal level create their informal organization to arrange the water distribution amongst each other. The selected division leaders are responsible to represent farmers and settle the discords. The farmers are able to control the water distribution only at certain level, as neither the default engineering design nor the prevailing conditions allow adequate flow control, proved by the RAP results.

In order to carry-out comprehensive analysis of PIM in Mubuku, the co-management is appraised through the design principles of common pool resources (CPR) defined by Ostrom (Ostrom 1992). The design principles are used to demystify the roles of actors and measure effectiveness of co-management. Yet, author alerts that design principles must be framed into specific context in order to avoid misinterpretation (Saunders 2014). Expert observation and face-to-face interviews with stakeholders, involving WUA managers, site engineers and farmers are the basis of the appraisal (Salman et al. 2020-d). The chapter builds on the introduction of the command area and complements the results of the RAP performance assessment in the previous chapter.

Principle 1. Clearly defined boundaries: “Both the boundaries of the service area and the individuals or household with rights to use water from an irrigation system are clearly defined.” – The setting of hydrological boundaries in Mubuku is relatively simple, consisting of one intake gate and adjacent conveyance structures. The water availability is limited by the water amount entering the scheme and distributed to farmers in rotational irrigation turns. The management responsibilities are attributed to stakeholders based on system layers. The O&M of the main canal operation, as well as the maintenance of secondary canal are carried out merely by governmental officers and WUA staff. The secondary canal operation, and O&M of the tertiary canals are assigned to farmers. Minor boundary violation occurs by pasturing farmers and household water need. The amount of unofficially taken water taken by them is negligible though.

Principle 2. Proportional equivalence between benefits and costs: “Rules specifying the amount of water that an irrigator is allocated are related to local conditions and to rules requiring labour, materials, and/or money inputs.” – Together the uniformity of the irrigation system with rotational distribution should ensure equity in supplied water quantity. Accordingly, each farmer pays flat water fee for irrigation services. If farmers believe that the water supply is not sufficient to match field water requirement, they can liaise with other farmers within the Division. By activating the role of Division leaders, farmers can re-distribute water upon agreement. However, inequal cross-division distribution causes deep-rooting conflict amongst users, as downstream farmers receive considerably less flow. Upstream farmers violate the established distribution rules despite of the enormous oversupply. The existence of “free-riders” is due to the lack of enforcement and monitoring mechanism that is not yet tackled by neither re-engineering solutions nor institutional rules.

Principle 3. Collective-Choice Arrangements: “Most individuals affected by operational rules are included in the group that can modify these rules.” – Farmers’ cooperative involves and informs farmers about operation-related decisions. However, farmers have little power to change pre-set rules and influence final decisions. This is well-illustrated by the fact that although the Cooperative is the budget holder, no meaningful maintenance and rehabilitation works have been carried out at tertiary level.

Principle 4. Monitoring: “Monitors, who actively audit physical conditions and irrigation behaviour, are accountable to the users and/or are the users themselves.” – No effective monitoring of condition, performance, risk and water distribution is in place. Although the main and secondary canals are in relatively good conditions, the extremely poor condition of tertiary infrastructures, ditches and drains eventually undermines the overall scheme performance. Nor the conflicts over distribution flaws are resolved through audit.

Principle 5. Graduated sanctions: “Users who violate operational rules are likely to receive graduated sanctions (depending on the seriousness and context of the offense) from other users, from officials accountable to these users, or both.” – Upstream farmers disobeying irrigation schedule are neither condemned, nor sanctioned. Wrongdoing without consequences, then, encourages farmers to continue unofficial water withdrawal. Adding to it, the official water supply is more than sufficient to meet field water requirement. Therefore, it cannot be argued that undue advantages rise merely from attempts to demonstrate power.

Principle 6. Conflict resolution mechanisms: “Users and their officials have rapid access to low-cost local arenas to resolve conflict between users or between users and officials.” – Conflict resolution mechanisms exist only within-division level, whereas Division Leaders are responsible to represent farmers and negotiate on water services. However, no other institutionalized rules are available to resolve conflicts.

Principle 7. Minimal recognition of rights to organize: “The rights of users to devise their own institutions are not challenged by external governmental authorities.” – The WUA function is currently integrated into the Cooperative’s work. The lack of de facto organization undermines the significance and power of independent WUA. The Cooperative is co-managed by state officials and farmers’ representatives though. The strong state control marginalizes farmers, who might consequently lose sense of common responsibility to make decisions. Organizing bottom-up institutions, for example building on the existing layer of Division Leaders, would certainly lead to more balanced management and stronger negotiating power.

Principle 8. Nested enterprises: “Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises.” – Farmers have no means to create two-tiered management structure due to their marginalized role in decision-making. Their role is minimized to O&M related activities such as canal maintenance and financial contribution. However, their ability to influence strategic decisions such as governance, conflict resolution, budget control and allocation, scheme development is limited.

5.1.3. The synthesis of the results

The results show that Mubuku irrigation system underperforms in both terms of equal water distribution and participatory service provision. The design and engineering configurations pre-determine the management options. To what extent the technical flaws are offset depends on the capability of the management. The RAP results show that abundant water resources alone are not sufficient to provide fair and equitable water service to all stakeholders. If management rules do not accommodate the persistent features of the infrastructure, the pre-existing disadvantages become particularly detrimental to farmers. Although the analysis of FPI proves that farmers have the option of cooperating on water distribution, the downstream farmers are systematically crowded out of good irrigation service. If management transfer is properly implemented and in-builds a monitoring mechanism for equal contributions and benefits, such discrepancies are not likely to arise. Presumably, the accounted disparity is a direct result of the pre-mature uptake of the management transfer policy. The qualitative assessment also shows that farmers' role in strategic decisions is not yet well-developed. The current two-tier management leaves a considerable gap in the responsibility sharing. The results of the assessment via Ostrom's principles are also consistent with the findings of the FPI that underpin the arbitrary modes of farmer participation. As presented in the literature review, the original concept of WUA proposes a bottom-up process, whereas farmers create their organizations in the frame of the national legislation. The legislations are usually flexible enough to allow farmers to re-negotiate the tasks with the WUA board. However, this is certainly not the case in Mubuku, whereas farmers create a virtual layer of Division leaders. This informal entity at division level indicates that farmers rather prefer a self-organized institution than the extension of the WUA's power. Huang et al. (2010) expresses the same concern "Although the international literature emphasizes the importance of farmer participation in the promotion of successful WUAs, practice often varies from principle. During the 2011 wave of the CWIM survey, there was little or no participation by farmers in China's WUAs. Only a few WUAs were created after consultations with farmers" (Huang et al. 2010). The case of Mubuku reinforces the issue of disconnecting WUA from farmers. If the establishment of WUA is driven merely by the state, it might become difficult to integrate and activate farmers in their new role. Although the review of the existing literature on management transfer attributes significant benefits to PIM, the experiences of real-term implementation bring a different picture. Farmers' attitudes to adopt management measures differ from one farmer to another. As the identified management measures are equally accessible to all farmers, the difference in pursued activities is presumably triggered by farmers' distinct backgrounds. The analysis and findings on the asymmetric and incomplete participation in management prove that PIM in Mubuku can be investigated only through the management layer of farmers, and any betterment of performance depends on the more active involvement of farmers, currently encapsulated in the role of service receiver. In order to delimit their potential, the first important step is to understand the individual engagement in irrigation management. To reflect on this research need, a method to measure farmers' individual engagement is proposed in the next step.

5.2. Results of measuring the motivation pattern in participatory irrigation management

In this section, our results regarding the measured motivation pattern of farmers in irrigation management are presented. The objective of this section is to understand which factors trigger farmers' more active participation. The section directly responds to the identified differences in undertaken management measures. The involved variables are described in the chapter 4.2.3. Empirical methods and specifications, whereas the specifications and the advantages of semiparametric and semi non-parametric methods are also thoroughly discussed. The applied SNP and SML models are estimated simultaneously, and Table 10 summarizes the results of the two models under each outcome variable.

Table 10: Results of SNP and SML models[6]

	Farmers' Participatory Index		**Attending irrigation training**		**Access to information**	
	SNP	SML	SNP	SML	SNP	SML
Education	0.93***	5.65***	0.25	1.24***	2.65***	5.32***
Gender	-0.29	1.15***	0.60	3.25***	-0.41	0.52
Age	0.67***	-0.89***	-0.11	-0.13	0.53***	0.37
Land size	-2.15**	-4.71***	-1.94***	-2.44***	-0.91	-5.99**

[6] Note on significance levels: * corresponds to $p \leq 0.10$, ** corresponds to $p \leq 0.05$, *** corresponds to $p \leq 0.001$.

Household size	0.10*	4.05***	0.11**	0.30***	0.02	-0.32***
Produced crops	-0.48	0.8***	1.97***	2.69***	-0.72**	-3.30***

From our results, the outputs showing consistent similarities between the two models are analysed. The interpretation of the results is based on the level of marginal significance and the sign of the estimates. It does not mean that outputs, which are not statistically significant, should be completely omitted. They still can be individually investigated in further research. The consistent and comparable estimates of the alternative methods are analysed per outcome variables:

i./ Participation: the modelling indicates consistent and significant effect of education, land and household size. Education has positive and statistically significant relationship at 1 percent confidence level. Farmers with higher education are arguably more willing to participate in irrigation management. The positive and significant relationship of household size is a particularly remarkable result in the context of Mubuku. The social objectives of the scheme target the absorption of unemployment and settlement of rural families by providing access to agricultural facilities. The positive effect of household size proves that family farming has major role in placing irrigated agriculture in the centre of economic growth and social policies. Finally, land size has negative and significant effect on participation at 5 percent confidence level. The reverse effect indicates that farmers with larger land size are less willing to participate in irrigation management. This result corresponds with the field observations by the RAP. Farmers, who could accumulate larger plot of lands through leasing contract or family heritage, spend less time in the field. According to the interviews, they hire daily workers to manage the irrigation turns. In return, farmers have less direct experience in irrigation and are less exposed to the anomalies of water distribution. Consequently, they might become less eager to take management responsibilities.

ii./ Attendance in irrigation training: the modelling identifies three variables having significant effect on attendance, namely land size, household size and produced crops. Similar to the participation, land size has negative and significant effect at 1 percent confidence level. Household size has positive and significant effect at 5 percent confidence level, meaning that farmers with larger households are more willing to attend irrigation training. The positive effect of produced crops indicates that farmers cropping others than maize are more likely to attend irrigation training. The field observation shows that the governmental maize programme is embedded in the work of the extension service. As maize-producing farmers have regular access to trainings, they are less likely to require specialized capacity-building programme. Another indirect justification of this result might be the special irrigation requirement of upland rice. Rice production is still in its infancy in the irrigation scheme. Rice-producing farmers are requested to keep pace with the cheap and high-quality import from Tanzania and other oversea trade partners. Farmers, therefore, are under pressure to improve their production technology to secure their market position.

iii./ Access to information: the modelling identifies two variables having significant effect on access to information, namely education and produced crops. Positive and significant effect of education shows that farmers with higher education have more likely access to information. Negative and significant effect of produced crops indicate that maize producing farmers have access to information. This latter result is supported by the fact that GoU provides organized and subsidized production programme for maize producing farmers that includes maize information system accessible by all farmers.

5.2.1. The synthesis of the results

Performing SNP and SML modelling provides robust results with mixed types of variables. Applying a semi- and semi-nonparametric test allows the analysis of ordinal and ranked data. This would probably result biased estimation while applying parametric models. Education, size of household, size of land and produced crops are the most frequent enabling factors for farmers' active participation in management. In order to frame the results in the context of PIM, the synthesis of findings is listed below:

i./ Modelling results positive and significant effect of education on all outcome variables, except the results of SNP in case of attendance in irrigation training. The positive effect of the education reinforces the importance of farmers' capacity-building in irrigation development and proposes education as pre-requisite of the successful outcome of PIM and IMT programmes. The results reinforce the conclusions of the literature review, in particular, the findings on farmers' readiness and ability to participate in management. As Goelnitz and Al-Saidi (2020) writes "On the one hand, it is not surprising that IMT reforms will fail if the target group is not adequately educated and empowered. Instead of merely pulling back from the scheme management, the state needs to provide more support in terms of awareness raising, clear institutional rules and active role in rehabilitating infrastructure including roads and main canals" (Goelnitz and Al-Saidi, 2020). Our results provide evidence on the importance of education to adopt management transfer. Undoubtably, education is the potential link between state-initiated PIM process and farmers' engagement. It cannot be assumed that the process of "learning-by-doing" can encourage farmers to be active members of the management. In particular, if the irrigated agriculture is approached from pro-poor context. Negative impacts such as failing yield have a considerably higher magnitude on farmers, who generate their income and daily subsistence merely from agriculture. It can be readily accepted that education as a soft measure of governmental programmes has as important role as any of the hard measures.

ii./ Household size proves to be a driver of farmers' involvement in irrigation management. Two participation variables have positive cause-effect relationship with household size. Larger households are strong incentives to engage farmers in irrigation management. Household size is an essential feature in subsistence farming, because positive outcomes of PIM might bring proportionally higher impact. The positive relationship between household size and participation is also important from sustainability point of view. Farmers having heirs, who are presumably involved in the daily agricultural activities, can successfully transfer their knowledge and experience. All too often, farming is put in the economic context of production. This research result is particularly important to prove that smallholder agriculture is not only a one-man enterprise. The outcome of the modelling shows that social factors such as family size have significant role in making agriculture more productive.

iii./ The modelling indicates reverse effect of land size on the outcome variables. Farmers with larger land size are less likely to be engaged in the management. Based on field interviews, this might be the impact of hired irrigators. As larger areas require more human labour, the landowners are self-isolated from day-to-day activities, such as irrigation, and eventually become neutral in issues related to irrigation development. The outcomes show that PIM can meet its objectives if farmers are directly involved in irrigation management without intermediary actors. Previous studies did not discuss the link between the management transfer and farming structure, more specifically: how does the direct employment influence the management transfer? Our result provides fresh perspectives to future studies.

iv./ The effects of produced crops are distinct amongst outcome variables. While maize producing farmers are less likely to attend irrigation training, they have access to information systems due to governmental programmes. It is less evident that even crop selection can alter farmers' preferences. However, the role of governmental production programmes must be recognized as enabling factors of PIM processes. Many of the governmental programmes incentivize farmers to produce more efficiently. As irrigation is one of the most meaningful intervention to increase the yield and adapt the climate change, management transfer cannot be overlooked. PIM process mainstreamed into governmental crop production programme seems to be viable solution to reinforce its objectives.

The motivation pattern plays essential role in achieving the ultimate research objective of measuring the effect of PIM programmes. Individual characteristics involuntarily influence the farmers' decision about taking management roles. Understanding the triggering factors provides information on how PIM programmes should be designed to achieve an impact-at-scale. However, the majority of recent literatures neglects the thorough investigation of farmers' motivation pattern by limiting the impact assessment on the pre- and post-assessment of PIM performance indicators. The novelty of the research lies in the approach of introducing and combining benchmarking methods that take into consideration the external and internal factors influencing farmers' decision. The approach, then, increases the robustness of the research results.

The next research objective arises directly from the results of motivation pattern. Our further analysis seeks to understand whether farmers engaged in the same participation measures have any particular similarity.

5.3. Clustering farmers by the participation in the irrigation management

In this section, the results regarding the farmers' clustering by their participation in irrigation management are presented. The cluster analysis is applied to group farmers by the inspection of the distance information (Hair, 1998). The larger the distance amongst variables, the more distinguished the clusters. This means that appropriate number of clusters is defined according to the increase in distance measure (Bakucs et al. 2014). Cluster analysis include the variables defined in the chapter 4.2.3. Empirical methods and specifications. The cluster tests and the results of Kruskal-Wallis are displayed in the Table 12. The left column displays the participation and characteristics variables, the middle columns show the performance of variables per each cluster, and the right column presents the results of Kruskal-Wallis test. An additional row is inserted to summarize the number of observations in the different clusters.

Table 11: Cluster analysis results[7]

	1	2	3	4	Kruskal-Wallis
Participation variables					
Irrigation training attendance	0.3	0	1	1	0.00***
Access to information	0	1	0.91	1	0.00***
Participation/FPI	0.5	0.38	0	1	0.00***
Farmers characteristics					
Gender	0.85	0.65	0.70	0.74	0.49
Education	1	1.45	1.20	1.61	0.01***
Age	4.5	4.52	4.65	4.61	0.62
Land size	1	1	1	0.79	0.01***
Household number	7.9	7.03	7.61	9.02	0.30
Profit	14.09	13.80	13.63	14.17	0.00***
Revenue	14.91	14.89	14.87	15.02	0.05**
Number of observations	20	29	34	39	

Based on the hierarchical clustering analysis, four clusters are defined. Non-parametric Kruskal-Wallis test is performed to understand if the cluster patterns are significantly different. The test confirmed that the four clusters are significantly different, so the results can be considered meaningful. To test the typological hypothesis of the clustering results, canonical linear discriminant analysis is applied as cross-validation method. The results are displayed in the Table 13-14.

[7] Note on significance levels: * corresponds to $p \leq 0.10$, ** corresponds to $p \leq 0.05$, *** corresponds to $p \leq 0.001$.

Table 12: Results of canonical linear discriminant analysis[8]

Funct.	**Cor.**	**Eig.**	**% of var**	**C. var.**	**Rat.**	**F-value**	**df 1**	**df2**	**Prob> F**
Funct. 1	0.94	8.16	0.58	0.58	0.01	198.3	9	282.5	0.00
Func.t 2	0.90	4.49	0.31	0.89	0.07	159.26	4	234	0.00
Funct. 3	0.78	1.54	0.11	1.00	0.39	181.57	1	118	0.00

Table 13: Structure matrix of standardized canonical discriminant analysis

	Function 1	**Function 2**	**Function 3**
Irrigation training attendance	0.87	-0.67	0.08
Access to information	0.61	0.79	-0.09
Participation/FPI	-0.38	0.40	0.96

Function 1 accounts 58 percent of the discriminating ability, whereas Function 2 takes 31 percent, and Function 3 shares 11 percent. Function 1 contains predictors of irrigation training attendance and access to information. Function 2 has predictors related to access to information and participation/FPI, whereas Function 3 only contains predictors of participation/FPI. According to the value of Prob>F, the means of groups are significantly different. The structure matrix shows the correlation

[8] Note on abbreviation: „Funct."=Function, „Cor."=Canonical correlation, „Eig"=Eigenvalue, „% of var"=Proportion of variance, „C.var"=Cumulative variance, „Rat."=Likelihood ration, „df"=degree of freedom, „F"=F statistics

between the variables and discriminant functions. Therefore, it can be concluded that the clusters have distinct variable pattern.

Our analysis shows that the numbers of cluster members range between 20 and 39. From Cluster 1 to Cluster 4, the participation performance of cluster members increases in order. While Cluster 1 has weak engagement in any of the participation variables, the members of Cluster 4 are fully engaged in all participation variables. From the three participation variables, access to information has the largest engagement performance, followed by irrigation training attendance and finally, FPI. The results show that the differences of the three participation variables amongst groups are statistically significant. The clusters represent specific characteristic patterns:

i./ Cluster 1 has the weakest aggregate participation performance. This is the only cluster that has no access to information channels. Farmers belonging to this cluster have the lowest education level. Based on the results of measuring farmers' motivation pattern, it is not surprising that farmers having the lowest education level are attributed to the group of weakest engagement in management. As previously discussed, education and participation have strong relationship. The group is dominated by male farmers, although the difference in gender is not significant amongst the four clusters. The profit and revenue level are around the average of the four clusters.

ii./ Cluster 2 still shows weak engagement in the three participation related variables but outperforms the Cluster 1. Cluster 2 is the only group that indicates no irrigation attendance and has lower engagement in FPI than Cluster 1. The performance related to profit and revenue is lower than Cluster 1.

iii./ Cluster 3 shows stronger engagement in two participation related variables, namely in irrigation training attendance and access to information. However, farmers are explicitly unengaged in FPI. The remarkable difference amongst all is that farmers in Cluster 3 generate the lowest revenue and profit. Farmers have relatively low education level and the highest age amongst the groups.

iv./ Cluster 4 involves the strongest engagement in all participation variables. In general, this group has the highest education level, highest household number, as well as the farmers in the group earn the highest profit and revenue amongst the groups. This group contains the farmers with smallest land size. The clustering results fully corresponds with the results of analysis of farmers' motivation in management. This cluster with the strongest engagement in irrigation participation aggregates the farmers with highest education, highest household numbers and smallest land size. The differences in realized benefits are statistically significant and show particularly interesting trend across the groups. Profit and revenue seem to correlate with the performance in FPI. Farmers in Cluster 3 have no engagement in FPI, while they gain the least revenue and profit. Cluster 4 has the highest engagement in FPI, and farmers in the cluster have the highest revenue and profit.

Our analysis includes farmers' financial gains as new aspect of the management transfer in Mubuku. The literature review presented in the dissertation proves that case studies of IMT/PIM apply multiple indicators to measure the impact. Some of the literatures apply over ten impact indicators in mixed dimensions. Nevertheless, one of the major conclusions of the literature review is the mistargeted indicator selection. Such case studies attempt to investigate the farmers' benefits through system efficiency indicators, such as the water use efficiency, the water supply, the water delivery service etc. However, these indicators have only indirect impact on the farmers. They contribute to the creation of optimal production condition, but they only serve indirectly the famers' ultimate objectives, the improving livelihoods. The yield productivity and profitability related indicators are more desirable if gains are measured in pro-poor context. Also, the yield increase is only suitable indicator if farming is at least partly subsistence-based or market conditions do not impose financial risk to the production. Otherwise, the direct income is the best targeted indicator to measure PIM impacts on farmers.

5.3.1. The synthesis of the results

Four farmer clusters are generated by the three participation variables (irrigation training attendance, access to information, FPI). The difference amongst clusters is statistically significant, thus resulting a specific characteristics pattern per cluster. Amongst the four clusters, the following characteristics are significantly different: education level, land size, profit and revenue. Cluster 4 outperforms the others in terms of the level of engagement in PIM. This cluster contains the farmers with the highest education level, smallest land size and largest household number. The outcomes of clustering, therefore, support the result of SNP and SML modelling that the participation variables and the characteristics of higher education, higher household number and lower land size have causal relationship. The particularity of Cluster 4 is that the farmers belonging to the group generate the highest revenue and profit. In contrary, the farmers in Cluster 3 have the least ability to generate profit and income. The farmers in the cluster are explicitly out of FPI. In general, it can be assumed that the participation/FPI variable has the largest effect on profit and revenue.

However, this can be only perceived at this stage. The farmers with the weakest performance in participation/FPI have the lowest profit and revenue. The clustering puts a special focus on the financial variables to analyse the farmers' ability to generate revenue and profit. The literature review highlights the major shortcomings of PIM impact evaluations. One of the major conclusions is the need of better-defined indicators that position the farmers in the centre of the assessment. As Smith (2007) writes "There are also significant risks that badly designed and managed irrigation can negatively impact on poverty. It is concluded that irrigated farming varies widely in its form and impacts and has diverse local attributes. Water resource management decisions must recognize this and be based on holistic and livelihood-centred assessment of irrigation benefits and costs that goes beyond food production objectives" (Smith 2007). Still, the overwhelming part of the applied indicators target efficiency related gains, such as irrigation efficiency, water supply sufficiency, etc. The chapter discusses that these indicators have only indirect impact on farmers, therefore, better fitting indicators should be defined to measure the success of PIM from farmers' perspective. Achieving a higher revenue and profit is the most significant farming outcome that supports the famers' livelihoods and the pro-poor objective of irrigated agriculture in Mubuku. Through it, the impact of PIM on farmers can be measured. Therefore, the clustering not only identifies the similarities amongst farmers by the participation variables but introduces the most potential indicators of measuring the impact of PIM on farmers. This guides the research toward the next step of investigating the relationship of participation/FPI and farming outcomes.

5.4. Results of estimating the effect of farmers' participation in irrigation management on farming outcomes

In this section, the results of measuring the direct impact of management participation on farming outcomes is presented. The section addresses the identified gaps in current literature and brings newfound approach for impact assessment of PIM. In order to rigorously measure the impact of participation on farming outcomes, four alternative methods used. The previous chapter provides solid ground for the outcome indicator selection. Also, it highlights the importance of FPI to directly measure the farmers' actual participation. Based on the model specification summarized in the chapter 4.2.3. Empirical methods and specifications, PSM is performed through a probit model. The differences in variables between the two groups are indicated in the Table 9 in chapter 4.2.3. Empirical methods and specifications. PSM requires fully balanced treatment independents to estimate average causal effect without biased estimates. Prior to the estimation, the observed systematic differences are successfully removed, as displayed in the Figure 11 about the balance plot prior and after matching.

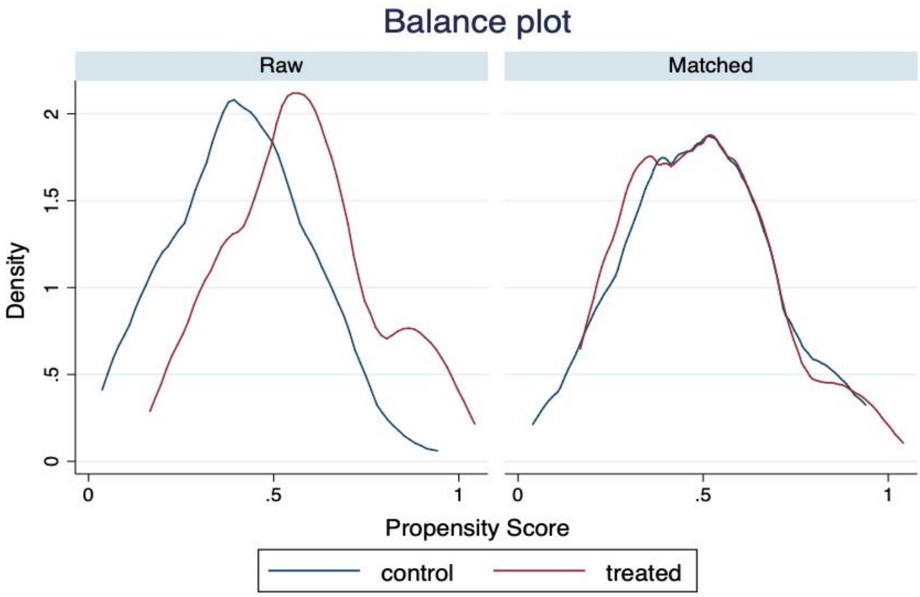

Figure 11: Balance plot prior and after propensity score matching

Prior to the matching, non-overlapping areas between control and treated group are observable, but after matching, the propensity score distribution shows decent overlap. Beyond the visual investigation, the balancing t-test presented in the Table 16 is performed to investigate whether the treatment independents are balanced in the matched sample.

Table 14: Balancing test results of treated and control groups

	Mean		% decrease	t-test	
Variable	**Treated**	**Control**	**%bias**	**t**	**p>t**
Education level	1.37	1.44	-10.0	-0.54	0.59
Gender	0.74	0.67	16.5	0.84	0.40
Age	4.59	4.42	22.9	1.03	0.30
Irrigation training attendance	0.72	0.74	-3.9	-0.22	0.83
Frequent experience of water shortage or waterlogging	0.33	0.29	7.6	0.41	0.68
Household number	8.11	7.61	13.5	0.91	0.36
Access to information system on production and water use	0.81	0.83	-4.7	-0.25	0.80

The improvement in treatment independents is confirmed by the balancing t-test, as the differences of education and irrigation training attendance variables between groups are successfully eliminated. Further improvement in almost all treatment independents can be observed after matching. The Table 17 summarizes the treatment effects estimated by different methods: difference in means in Column 2, regression adjustment in Column 3, propensity score matching in Column 4 and entropy balancing in Column 5.

Table 15: Treatment effects for the outcome of revenue, profit and productivity[9][10]

	Mean difference	**Regression adjustment**	**Propensity score matching nn (1)**	**Entropy balancing**
Average yield of maize production	0.29***	0.39***	0.33***	0.37***
standard error	0.12	0.14	0.17	0.15
t stat	2.49	2.76	1.99	2.39
Average revenue per acre	474***	437.63***	584.29***	408.75***
standard. error	126.75	140.43	179.25	148.73
t stat	3.74	3.12	3.26	2.75
Average profit per acre	453.95***	523.74***	427.47***	463.01***
standard. error	103.53	112.92	150.99	120.02
t stat	4.38	4.64	2.83	3.86

Each estimation indicates positive and significant effect of FPI on farming outcomes:

i./ According to the PSM model results by 1 to 1 nearest neighbour matching, maize-producing farmers in the non-participating groups could achieve 0.33 ton per acre higher yield if they participated in irrigation management. Regression adjustment and entropy balancing results show even higher gain by participation at 0.39 ton and 0.37 ton per acre maize yield. The average maize yield is 2.04 ton per acre measured in dry

[9] The nn (1) refers to the nearest neighbor matching, whereas the individual from the control group is matched to a treated individual that has the closest propensity score. The 1:1 matching selects one treated individual to one control individual with the smallest distance.

[10] Note on significance levels: * corresponds to $p \leq 0.10$, ** corresponds to $p \leq 0.05$, *** corresponds to $p \leq 0.001$.

biomass, consequently, farmers can achieve a yield increase of 16 to 19 percent per season. Yield increase, however, results not only economic benefits, but social benefits. As agriculture is partly subsistence based, improved productivity substantially contributes to household food security. Also, the results confirm that PIM is well aligned with national programmes to improve maize self-sufficiency.

ii./ PSM suggests that non-participating farmers could achieve higher revenue by 586 thousand UGX per acre if they participated in irrigation management. This difference can be translated into significant additional revenue if calculated to total farm size (3.4 ha) in double-cropping. Similar to PSM, entropy balancing, and regression adjustment result higher revenue outcome by 408 and 437 thousand UGX per acre. However, revenue itself is not sufficient to assess the success of PIM. If cost of production proportionally increases due to the additional cost of participatory management, the realized gains are negligible. Therefore, it must be evaluated together with the differences in profit.

iii./ PSM outcome shows that 427 thousand UGX per acre more profit could have been achieved if control group participated in irrigation management. The profit gain estimated by entropy balancing and regression adjustment is 463 and 523 thousand UGX per acre. This result is particularly interesting in the light of the current minimum wage in the country. International Labour Organization (ILO) established the Minimum Wage-Fixing Machinery Convention in 1928. Communication between ILO and GoU has been initiated to readjust the national minimum wage rate, which has not been changed since 1984. Due to date, the monthly minimum wage remains 6 000 UGX (approximately 2.5 USD). Although Committee of Experts by ILO recommended the timely adjustment, and GoU agreed on an increase to 75 000 UGX, the change of minimum wage has not been signed into effect. Considering this fragile work environment coming from insufficient social policy, people can attain stable and decent standard of living only by improving the profitability of their venture. In this context, the positive effect of PIM on profit is remarkable. Farmer can obtain nine times higher income than the proposed minimum monthly wage simply by management participation.

5.4.1. The synthesis of the results

The effect of PIM is estimated by four alternative methodologies: difference in means, regression adjustment, propensity score matching and entropy balancing. We presented a novel approach to estimate the direct gains of participatory management by setting the scope explicitly for farmers and measuring the differences based on direct engagement in management. Each model results positive and significant effect of PIM. The farmers in participating group have a remarkably better performance regarding the three outcome variables: yield, revenue and profit. According to the aggregate results of several models, gains of participation range between 0.29 to 0.39 ton per acre maize yield increase, 408 to 584 thousand UGX per acre revenue increase and 427 to 523 UGX per acre profit increase. Profit can be considered as the most powerful outcome when measuring the impact of PIM related development programme. This particular indicator gives information on how irrigation can improve the rural livelihood in developing countries. Given the fact that agriculture is the mainstay of 72.4 percent of Ugandan, the performance improvement is essential (World Bank, 2018). Taking only the maize profitability, the generated profit per participating farmers exceeds 25 percent. The current literatures suggested the further development of PIM impact evaluations. The studies investigating PIM through the states and WUAs overshadowed those, which attempted to understand the farmers' positions. The systematic review clearly underpinned that the literatures about the farmers-centred assessment require further assessments and more scientific proof. Our research addressed all identified shortcomings of the literatures and presented novel approach for future impact assessments. Our results contribute to the literature by confirming the relevance and viability of PIM at farmer level. It proves that PIM has positive effect on livelihoods if farmers are strongly engaged in the management transfer. On the other side, the approach is novel not only in the sense of farmers' differentiation by real-term participation. This approach also helped overcome the data paucity that is often a constraining factor in developing countries. As Samad and Vermillion (1999) conclude "In most irrigation systems in developing countries, time-series data, particularly relating to irrigation releases and crop yields, may not be readily available…In such situations a comprehensive 'before' and 'after' comparison of performance may not be feasible". In fact, experimental research methods are often limited by the lack of data, the inappropriate environment to conduct a field experiment, the difficulties in reaching out to the rural and remote population, the lack of local experts to support the research and the time constraint. The literature review showed that the wealth of information on PIM still contains limitations regarding the rigor of applied methodologies, and eventually the reliability of results. Using alternative methodologies, in particular quasi-experimental methodologies enable the future research to extend the analysis to data-poor environment without compromising the robustness of results. The novelty of this research is grounded in this approach.

6. DISCUSSION AND CONCLUSIONS

The dissertation introduced alternative methodologies to evaluate the success of PIM in the context of developing countries. A systematic review was conducted to reveal the core research needs related to an adequate impact assessment. Based on the systematic review, the dissertation concluded that the current literatures suggest further advances in PIM analysis in terms of geographical balance, indicators selection, scope for irrigation scheme types and robustness of applied methodologies. A case study approach was selected to demonstrate the novel methods that complies with the encountered research requirements. Mubuku irrigation scheme in Uganda was the pilot area of the research, as the features of irrigation scheme fit well into the context of the research. The irrigation scheme is located in deprived rural area of a least developing country that aspires its economic growth through agriculture.

The interdisciplinarity of the research topic is well presented by the fact the case study required an in-depth investigation of the hydrological, engineering and socio-economic conditions. In order to acquire structured information about the overall performance, Rapid Appraisal Procedure was applied to assess the irrigation performance of the scheme through efficiency and water service indicators. The analysis unfolded the underlying dynamics that had been not apparent by simple field observation. One of these issues is the contrary results about water distribution. Despite the enormous over-supply of irrigation water in the scheme, downstream farmers are heavily exposed to water stress due to the inequal distribution amongst users. The paradox arises from the poor institutional arrangements amongst stakeholders at different management layers. This fact is the evidence that although PIM should have already tackled the inequity by strengthened collaboration of farmers, the real-term implementation has fall short of its potential. The appraisal of the command area stressed the importance of the contextualization of PIM by interdisciplinary approach, involving distinguished fields of sciences. The main lesson of the appraisal is that PIM cannot be contextualized merely by a policy or socio-economic assessment. The future PIM programmes must always integrate the various hydrological, agricultural and engineering conditions, because such conditions have a decisive role in the feasibility of the implementation. To obtain further information on the current status of PIM in Mubuku, the research continued with a theoretical comparison of the desirable and current status of institutional arrangements. Ostrom's design principles were an early attempt to establish a critical requirement system of the self-managing irrigation schemes. Mubuku case study was evaluated along the eight principles. The qualitative assessment provided an evidence that the current implementation stage of the participatory management is somehow derailed by disconnecting farmers from the elementary management functions. Farmers, their representations and state actors do not form a single entity, but a multilayer management system is created, where farmers remain with an unduly limited role in management. Such qualitative assessment is useful to identify the symptoms of the implementation failures. Ostrom's design principles, for example, provide a solid framework for the optimal management setting. The future research, of course, can define their own desirable management mechanisms. But, the vision of such optimal management mechanism should be an essential part of impact assessments. The qualitative assessment, however, is not sufficient to reveal the root causes of the asymmetries in PIM implementation. Design principles reflect on how the features of co-management departure from the initial objectives of PIM, but the analysis must be complemented with a fact-finding research.

Previous studies defined multiple bottlenecks of obtaining robust and meaningful assessments. Such bottlenecks are the lack of historical data and recorded evidence of the scheme management. Also, most of the irrigation schemes are under-resourced in terms of human capacity and data acquisition systems. The future research in developing countries have to overcome physical barriers concerning the access to remote irrigation schemes, poor road and communication facilities and time constraints. An experimental research design that requires controlled environment would involve assumptions on static conditions, thus explicitly attributing the measured effect to the independent variable. In order to address this issue, this research relied on the Farmers Participatory Index. The index measures the actual involvement of farmers in irrigation management to differentiate participating and non-participating groups. Distinguishing farmers enables, then, a quasi-experimental research design that evaluates PIM in a comprehensive manner. Such comprehensive evaluation spans from measuring farmers' involvement to the impact assessment. If researchers can measure farmers' direct interaction with the given development programme, the results more accurately reflect on the social reality.

Semiparametric and semi-nonparametric methods were used to analyse the farmers' motivation pattern in participatory management. The research methods were selected by taking into consideration the types of explanatory and dependent variables. The method considered farmers' observable characteristics as explanatory variables and identified which of them are enabling factors of participatory management. The results underlined that education and household size have positive and significant effects on the participation, while the farm size has negative and significant effect on participation. The findings have several socio-economic merits that can be mainstreamed into future development programmes, such as participatory irrigation management. The research confirms that identification of driving factors are powerful incentives to prompt farmers to embrace efforts to adopt participatory management. This will substantially contribute to the success of participatory programme designs.

Cluster analysis was performed to investigate the distinguished features of farmer groups on the basis of their involvements in participation. The cluster analysis identified four groups with different levels of engagement in three participatory measures (farmers participation index, attendance in irrigation training and access to information). The clustering reinforced the results of the semi and semi-nonparametric estimations by providing statistically significant differences in education and farm size. Furthermore, the four clusters are statistically different in terms of two additional characteristics: profit and revenue. These latter two seemingly correlate with the farmers participation index. The clustering was a critical step to delineate the characteristics pattern per farmers group. It also highlighted how characteristics change according to the different levels of engagement in participation. While implementing development programmes, taking into account the diverse background of all individuals is cumbersome. Clustering helps identify the major characteristics patterns that might be an entry point to drive the implementation towards more inclusive process. In the research, clustering had a secondary objective by shaping the final indicator selection of impact assessment. The differences in profit and revenue across the groups refer to the effect of participatory management on farming outcomes.

The average treatment effect of farmer participation index on farming outcomes was estimated through four alternative methods: difference in means, regression adjustment, propensity score matching and entropy balancing. The research question was built on counterfactual analysis: what increase in profit, revenue and yield could non-participating farmers achieve if they participated in irrigation management? The four alternative methods were simultaneously performed to reinforce each other's results. The results of the methods showed consistent significant and positive effect of participatory management. Yield increase was measured only amongst maize growing farmers. The measured increase ranges between 16 and 19 percent, respective to the estimation method. The revenue increase varies from 408 to 586 thousand UGX per acre, while profit from 427 thousand UGX to 523 thousand UGX per acre. The remarkable results show that participatory irrigation management has positive effect on farmers' livelihood. If future PIM programmes can achieve such increase in farming outcomes, their relevance to the livelihood development programmes is justified. However, the PIM programmes require long-term monitoring and a rigorous impact assessment to ascertain their benefits. The future implementations might consider this fact and in-build a monitoring mechanism right at the design phase.

The impact evaluation of PIM is key step of the irrigation related development programmes to address the efficient use of water in the light of climate change, household food insecurity and low-income of smallholders. National policies implement PIM as the farmers' institutionalized contribution through the intermediate management layer of WUA, which, in turn, is often the product of a top-down state policy. Analysing PIM in the context of farmers' direct involvement in management is of vital interest. This research attempted to close the gap between farmers and management by overseeing the PIM process from farmers' perspective. Similar to many of the small-scale irrigation schemes in developing countries, Mubuku settlement scheme is under a growing pressure to deliver maximum benefits for farmers, who rely on agriculture to improve the household food security and reach decent income. Transferred management measures can be expected to be overtaken only if they do not jeopardize the farmers' financial situation, their effects are measurably positive, and their gains are well demonstrated. The research reveals positive and significant effect of PIM on productivity, revenue and profit, which can be considered certainly the most powerful impact indicators in developing countries' context. The results, then, endorse the on-going efforts of promoting PIM.

The main lessons are that i./ feasible implementation strategies of participatory management arise from a good and in-depth understanding involving social and engineering sciences, and contains information on hydrological, social, economic and environmental aspects; ii./ to the extent that transferred management practices are grounded in comprehensive evaluation. Yet poor farmers' irrigation schemes rarely provide sufficient information and historical data. iii./ Instead of forcing conditional research methodologies into such context, alternative methods must be considered. Such methods should provide robust results despite the resource and prior information constraints, for example, by counterfactual analysis. The case study proves that introduced sequence of research methods over the entire process of PIM brings robust results even in particularly remote areas such as Mubuku in Uganda. iv./ The success of implementation depends ultimately on farmers, who are still often either neglected or self-excluded from management responsibilities. The identification of triggering factors can, however, prompt farmers' engagement to eliminate the disparities in management transfer. Less clearly understood that v./ not all impact indicators of PIM might be relevant for farmers, in particular, if they do not entail direct benefits for them. Although, the wealth of studies on PIM impact assessment forms a rich pool of scientific background, the majority of the studies do not clearly distinguish the expectations amongst the management layers of state, WUAs and farmers. If development programmes are meant to achieve pro-poor objectives, food security and livelihood related indicators are the most powerful proxy of the success. vi./ The little-explored benefits of PIM on farmers' social conditions are not well-demonstrated due to the mistargeted indicators. In return, farmers, who are not informed on possible gains, are not keen to embrace the programmes. If the positive effects of PIM are backed up by scientific results drawn from robust research, future implementation of the programmes can be better crafted, and such programmes can be also consistent with socio-economic and environmental objectives. vii./ Finally, PIM can be an effective tool to support the cross-cutting objectives of livelihood development and integrated water resource management programmes.

6.1. Limitations and the future of the research

The current chapter provides an overview of the limitations encountered and the future of the research.

6.1.1. Limitations of the research

The limitations are divided to methodological limitations and the limitation of the researcher.

The methodological limitations are the following:

- The research was conducted in data-poor environment. Uganda has not established a meaningful statistical database regarding the research-relevant aspects of water management and agriculture. Furthermore, the assessment of data reliability through official national or micro-level data could have not produced a meaningful result. Therefore, the applied datasets, without exception, are obtained through primary data collection. This context-specific research design requires careful considerations while transferring the results to other locations.
- Like the farmers survey, the agriculture and water data required by the performance assessment was obtained through installed devices and instruments. Due to financial, human-resource and time constraints of this investment, such infrastructure was developed only in Phase II as the most representative section of the irrigation scheme.
- The irrigation systems represent a large heterogeneity, therefore, research must assess the system features case by case. This heterogeneity determines the conditions of the management transfers, thus the available management activities. The results of benchmarking and assessment can hardly be wholly transferred to another system. The identification of management activities and the assigned weights are built on field observation in the research. Although this issue was addressed throughout the implementation by matching theory and field condition, this process might include a certain arbitrariness.

The limitations of the researcher are the following:

- Due to the communication barriers (native indigenous language), the farmers survey was supported by interpreters. Although direct communication is the preferred way for a researcher to correctly interpret the point of the interviewees, the research was done through the interface of simultaneous translation.

- Management transfer is influenced by culture and social aspects. The encountered incompleteness or failures in management transfer might have underlying causes coming from hidden cultural differences that could be investigated and unlocked only through the integration into the community.

6.1.2. The future of the research

The advances in theory and practice of implementing community-based management models are already apparent. The development pathways of the research are grouped into i./ addressing limitations related to methodology, and ii./ expanding the framework in response to the global challenges.

The issues related to irrigation system management, involving O&M have been the subject of longstanding debates. Standardization of management process while taking due account of the heterogeneity of the irrigation systems is a two-fold problem that researchers must face. A further difficulty is to understand in which management activity farmers can be effectively involved. Therefore, the research will be further improved to properly address this issue:

- To fully understand the expected and actual management activities, including O&M and financial contributions, a well-constructed inventory protocol and on-going records are required. Such protocol should be created as per the major irrigation system categories and involve a certain flexibility to ensure its applicability in any irrigation scheme. Up to now, no global inventory protocol has been created to facilitate the work of public scheme management. As clearly defined management activities are the backbones of management transfers, this methodology step of identifying the typologies of activities will be supported by methodology development. The re-visited RAP methodology is an attempt to support this effort. Furthermore, there is a renewed focus on irrigation asset management. Such global protocol and the establishment of asset management framework will help eliminate any bias.

Due to the increasing pressure of the growing population and climate change on natural resources, the attention of international development will be increasingly refocused on the management transfer. Beyond geographical expansion of the current research and the implementation of similar methodology approach in other countries, management transfer has its raison d'être to support the two global challenges, namely the gender equity and climate change adaptation. Therefore, the research will be brought forward and contribute to the on-going efforts:

- PIM by its definition relies on the equal and inclusive contribution of community members to management. Women, however, have often restricted or no access to productive assets, such as land or water resources. Over history, they have been crowded out of ownership rights, decision making, or governance of natural resources. This fact is also well demonstrated in the Mubuku case study. The next important step of this research will be a gender-disaggregated analysis, whereas management activities will be assessed from women's perspective and driving factors of women engagement will be investigated.
- While the achievement of internationally agreed target of emission containment is becoming questionable, the need of introducing efficient

climate adaptation strategies requires closing the gap between adaptation and mitigation finance. Up to date, mitigation has taken the vast majority of global climate finance, but the current investment pathways show some signs of moderation in favour of adaptation. While mitigation is mostly approached from regulatory and decision-making level to control the emission, adaptation must build around end-user level, who directly sustain the devastating impacts. Community based programmes and the closely related capacity-development will be repurposed to become a proxy of climate change adaptation. As irrigation is the number one adaptation strategy in agriculture, PIM will be in the forefront of adaptation programmes. In the next step, the research will seek the PIM implementation modalities that support not only the farmers' profitability but their ability to adapt to climate change. The causal relationship between farmers' engagement and successful adaptation strategies will be also investigated.

7. NEW SCIENTIFIC RESULTS

1. The dissertation highlighted the importance of approaching participatory irrigation management from a multidisciplinary aspect. A well-established irrigation performance assessment tool, the MASSCOTE-RAP was applied to delineate the distinguished management measures amongst multiple institutional layers: state, WUA and farmers. The results showed that although understanding the system performance is crucial to set-up hydrological and administrative boundaries of irrigation management, a successful management transfer goes beyond the flaws of engineering design.
2. The research showed that farmers in relatively homogenous communities do not engage in participatory irrigation management at the same degree. The results showed that education and household number play vital role in participatory management, as they have positive and significant impacts on active participation in management. In contrary, land size has negative and significant impact on it. This result proves that management responsibilities are less likely to be successfully transferred without proper knowledge or sufficiently large household. The negative effect of land size highlighted the fact that farmers without direct experience and daily work in irrigation are rather reluctant to take role in management. Hence, participatory management requires farmers' personal commitment.
3. The research introduced a novel research approach to measure the level of engagement in irrigation management. Farmers participatory index was computed to measure the impact in "with-or-without" context. The dissertation, then, overcame the major obstacles of previous literatures to establish robust research method, namely: time and geographical

constraints, varying conditions over the implementation period and diverse backgrounds of farmers.

4. Through the process of understanding the drivers of management transfer, the dissertation identified performance indicators to measure the farmers' benefits. Instead of the widely used performance indicators of system efficiency and cost recovery, the dissertation narrowed the set of indicators to the ones directly contributing to the farmers' livelihood. This feature is considered crucial in a developing country context.
5. The dissertation introduced a counter-factual analysis to measure the impact of PIM. The research approach was proved to be suitable for the estimation of the PIM benefits at individual basis. Measuring the benefits in disaggregated manner and through quantitative methods provided a fresh perspective for impact assessment in complex development programmes such as the management transfer. The research proved that PIM has positive impact on poor farmers, thus supporting the viability of management transfer in development programmes.

8. SUMMARY

Farmers' participation in the irrigation management grew into a key strategy due to the recognition that traditional, state-driven management mechanisms are not efficient enough to meet farmers' expectations and exploit the potential of irrigated agriculture. Water User Association (WUA) is defined as a formal and bottom-up organization of farmers for the purpose of managing a common irrigation system. However, the actual participation of farmers remains poor in the reality. Although dozens of countries have already introduced programmes on irrigation management transfer, their effectiveness is still not sufficiently backed-up with scientific results. The challenges of implementing management transfer are numerous including socio-economic diversity, cultural background, resource endowment and scarcity, agricultural markets, production structure etc. The overall goal of the research is to provide a complex analysis of participatory irrigation management from farmers' perspective in developing countries. It draws conclusions on how research methodologies can help to contextualize and measure the impact of irrigation in a particular institutional setting such as participatory irrigation management. To accomplish this goal, the research is phased into a stepwise methodology consisting of four intertwined strands: i) qualitative assessment of farmers' role in irrigation management; ii) measuring the drivers of farmers' engagement in irrigation management, iii) categorizing and characterizing farmers by participation in irrigation management, iv) estimating the effects of participatory irrigation management on farming outcomes.

Despite of the ample number of literatures analysing participatory irrigation management (PIM), the systematic evaluation of the impacts is

still its infancy. In order to reach better understanding of the measured effects, a systematic review is conducted to investigate the quality of existing literatures on impact evaluation and draw conclusions from their findings. 148 performance indicators from 42 research articles are analysed and the major shortcomings of PIM evaluation are identified, namely i./ the underrepresentation of smallholders, ii./ the lacking diversification of irrigation scheme size, iii./ the geographical imbalance amongst case studies, iv./ the rigor of applied methodologies and v./ misdirected performance indicators setting the scope mostly for efficiency and productivity. The research applies a case study approach to respond to the abovementioned bottlenecks of existing literatures. The research is conducted in Mubuku irrigation scheme in Uganda, a small-scale scheme incorporating smallholders in a deprived rural area of the country. In order to properly describe the scheme and understand the prevailing hydrological, engineering and socio-economic performance, Rapid Appraisal Procedure is conducted. The method reaches the conclusion that the massive oversupply of irrigation water leads to a low irrigation efficiency. To make matters worse, poor institutional arrangements lead to distributional flaws, ultimately to the inequity amongst farmers. As a result, some farmers are threatened by the overirrigation, and the others by water stress. The method, then, is used to delineate the actual management measures taken by farmers (14 in total). These management measures can be divided into three main responsibility domains: management, financing and maintenance. The sampling process involved 122 farmers out of 167 living in Mubuku scheme. Their socio-economic characteristics, production technologies, farming outcomes and participation in the identified management measures are registered in the course of an agricultural season in 2018.

The qualitative assessment shows that farmers' role in strategic decisions is not yet well-developed. The current two-tier management between WUA and farmers leaves a considerable gap in responsibility sharing, despite that, WUA and farmers represent conceptually the same organizational layer. In reality, their role, objectives and authorities are distinct though. The case of Mubuku reinforces the issue of distinguishing WUA from the farmers. If the establishment of WUA is driven merely by the state, farmers become encapsulated in the "service-receiver" role. In order to delimit their potential, understanding their individual engagement in irrigation management is of vital interest. In order to measure the degree of farmers' participation in irrigation management, farmers participatory index (FPI) is computed. FPI pools farmers into "participating" and "non-participating" groups on the basis of their degree of engagement in participatory management. As result, FPI is the proxy of farmers' active role in PIM. FPI confirms that farmer communities are diverse and complex in terms of the attitude and the motivation.

Semi- and nonparametric tests are applied to understand which factors trigger the more active participation. The results show that education, size of household, size of land and produced crops are the most frequent enabling factors for undertaking the management responsibilities. Education is identified as a potential link between the state-initiated PIM process and the engagement. The research shows that the process of "learning-by-doing" should not be considered a feasible process to make farmers active members of the management. Adding to it, larger household size proves to be a powerful incentive to engage farmers in irrigation management. The household size is essential in subsistence farming, because positive outcomes of the management transfer might result an impact-at-scale. The modelling indicates negative effect of the land size on the participation. Due to the hired labour to carry-out the daily works, the landowners are disconnected from the day-to-day activities, such as the irrigation, and eventually become neutral in issues related to the irrigation development. The outcomes show that the participatory management can meet its objectives if farmers are directly involved in the irrigation management without intermediary actors.

Clustering is performed to identify the characteristics patterns that might be an entry point to drive the implementation of participatory management towards more inclusive process. The cluster analysis identifies four significantly different groups with different levels of engagement in three participatory measures (farmers participation index, attendance in irrigation training and access to information). The clustering reinforces the results of the assessment of drivers through showing statistically significant differences in the education and farm size variables. Furthermore, the four clusters are statistically different in two additional characteristics: profit and revenue. Based on the results, these variables seemingly correlate with the FPI. Hence, clustering is a critical step to delineate the characteristics pattern per farmers group and to denote the most suitable performance indicators of management transfer.

The treatment effect of management transfer is estimated by four alternative methodologies: difference in means, regression adjustment, propensity score matching and entropy balancing. Given the particularity of the pilot area, notably the remote location, the lack of historical data, the cost of the research and the changing environment, a counterfactual analysis was applied in the framework of the quasi-experimental research method. The novel approach is introduced to estimate the direct gains of participatory management by setting the scope explicitly for farmers and measuring the differences on the basis of direct and individual engagement in the management. The direct engagement is measured through FPI to distinguish farmers' groups. Positioning farmers into the centre of the research is through the beforementioned indicators (revenue and profit) and complemented with the performance indicator of yield. Each method results positive and significant effects of management transfer on the indicators. The farmers in participating group have remarkably better performance in the three outcome variables, namely yield, revenue and profit. Therefore, the research proved that PIM can be an effective tool to support the cross-cutting objectives of programmes related to livelihood development and integrated water resource management.

9. ÖSSZEFOGLALÓ

A gazdálkodók öntözési döntéshozatalba történő bevonása fontos stratégiává nőtte ki magát, miután felismerték, hogy a hagyományos, központilag irányított öntözőtelepek nem kellően hatékonyak a gazdák elvárásaihoz. Emellett az öntözéses mezőgazdaságban rejlő lehetőségek is kiaknázhatóbbá válnak. A vízitársulatok eredeti céljuk szerint alulról szerveződő gazdálkodói csoportok, melyek megalapítása az új politika bevezetésének mérföldköve volt. A gyakorlat azonban azt mutatja, hogy a vízitársulatok sokkal inkább állami kezdeményezés részeként valósultak meg, és ezáltal a gazdálkodók öntözés menedzsmentben valós részvétele és hozzájárulása meglehetősen alacsony. Mára számos ország megalkotta és bevezette a részvételi öntözésirányítás modelljét, az ezen szervezeti keretek hatékonyságmérésére vonatkozó tudományos eredmények azonban hiányosak. A részvételi öntözésirányítás megvalósítása számos kihívással áll szemben, többek közt a megvalósítást jellemző társadalmi-gazdasági diverzitás, a kulturális háttér, az erőforrás-ellátottság, a piaci mechanizmusok és a termelési szerkezet. A kutatásunk általános célja a fejlődő országok részvételi öntözésirányításának teljeskörű elemzése és hatásainak a gazdálkodók szemszögéből történő bemutatása. A kutatás célja továbbá, hogy bemutassa a különféle kutatási módszertanok alkalmazhatóságát a részvételi öntözésirányítás hatáselemzésében. A kutatási cél elérése érdekében a dolgozat négy egymáshoz szorosan kapcsolódó és egymásra épülő elemzési részre épül: i) a gazdálkodók öntözésirányításban betöltött szerepének kvalitatív értékelése; ii) a részvételen alapuló öntözés ösztönző tényezőinek felmérése, iii.) a gazdálkodók csoportosítása az öntözésben való tényleges részvételük alapján, iv.) a részvételi öntözésirányítás hatáselemzése a termelés eredményeire vonatkozóan.

A részvételi öntözésirányítás kiterjedt szakirodalommal rendelkezik, azonban a hatások strukturált értékelése még gyerekcipőben jár. A rendelkezésre álló szakirodalmi források szisztematikus elemzése általános betekintést nyújt a részvételi öntözésirányítást vizsgáló kutatásokba és a mért eredményekbe. Az elemzésben felhasznált 42 cikkből összesen 148 teljesítmény indikátort elemeztünk, melyek alapján az alábbi hiányosságokat tártuk fel a részvételi öntözésirányítás kapcsán: i./ a kisgazdálkodók képviselete nem kielégítő; ii./ a kisléptékű öntözőrendszereket elenyésző arányban vizsgálták; iii./ az esettanulmányok földrajzilag koncentráltak; iv./ az alkalmazott módszertanok nem kellően megalapozottak; v./ a választott teljesítményindikátorok gyakran pusztán a rendszerhatékonyság és termelékenység mérésére korlátozódnak. A meglévő szakirodalom fent említett hiányosságaiból kiindulva a kutatás esettanulmányos megközelítést alkalmaz. A kutatás helyszíneként a Mubuku öntözőrendszert választottuk, amely Uganda egy hátrányos helyzetű vidéki térségének kisbirtokosait látja el. A „Rapid Appraisal Procedure" („Gyors Értékelési Módszertan") segítségével teljeskörű, hidrológiai, mérnöki és társadalom-gazdasági jellemzőket magában foglaló elemzést tudtunk végezni. Az eredmények alapján elmondható, hogy a terület erős túlöntözése miatt a jelenlegi rendszerhatékonyság rendkívül alacsony. Ezenfelül a jelenlegi hiányos szervezeti keretekből fakadóan a gazdálkodók közti vízelosztás egyenlőtlen, így egyes gazdálkodókat a túlöntözés, más gazdálkodókat az aszálykár fenyegeti. Az elemzés lehetőséget biztosított arra is, hogy különféle öntözésüzemeltetési tevékenységeket fogalmazzunk meg (összesen 14 tevékenységet). Ezek a tevékenységek a következő három nagy csoportba sorolhatók: irányítás, finanszírozás és karbantartás. Az öntözőtelep által érintett 167 gazdálkodóból 122 vett részt a mintavételben. Kérdőíves felmérés segítségével vizsgáltuk a gazdálkodók társadalmi-gazdasági jellemzőit, az alkalmazott termelési technológiát, illetve a gazdálkodásuk eredményét és az öntözésüzemeltetési tevékenységben való részvételüket egy egyéves időszak során 2018-ban.

A kutatás első részében a gazdálkodók öntözésüzemeltetésben betöltött szerepét vizsgáltuk kvalitatív módszertan segítségével. Az eredmények alapján a gazdálkodók szerepe a stratégiai döntéshozásban rendkívül korlátozott. A vízitársulatra és a gazdálkodókra épülő kétlépcsős irányítás jelentős hatékonyságromláshoz vezet, melynek oka az üzemeltetéssel kapcsolatos felelősségmegosztás, annak ellenére, hogy a vízitársulat és a gazdálkodók a koncepció szerint egy szervezeti egységet képviselnek. A gyakorlatban azonban mind a szerepük, a szervezeti céljaik és hatásköreik elválnak egymástól. A Mubuku öntözőtelepen végzett hatástanulmány alátámasztja ezt az általános jelenséget és rámutat arra, hogy amennyiben a vízitársulatok pusztán állami kezdeményezés eredményeként jönnek létre, a gazdálkodóknak csupán a külső megfigyelő szerepe jut. Ahhoz, hogy a gazdálkodók bevonhatók legyenek az öntözésirányításba, fontos megvizsgálni az aktív elkötelezettségüket befolyásoló tényezőket. A dolgozatomban Gazdálkodói Részvételi Indexet (GRI) számoltam annak érdekében, hogy mérhető legyen a gazdálkodók egyéni részvétele az öntözésirányításban. A GRI alapján a gazdálkodókat „résztvevő” és „nem résztvevő” csoportokra osztottam. Az index segítségével kiszámíthatóvá válik a valós részvétel az adott üzemeltetési tevékenység ellátásának arányában. Az index megalkotása során világossá vált, hogy a gazdálkodók elkötelezettsége és ebből adódóan aktív részvétele az öntözésüzemeltetésben nagyban függ egyéni motivációjuktól.

A részvételi öntözésirányítás ösztönző tényezőinek feltárása félparaméteres és félig nem paraméteres módszerekkel történt. Az eredmények alapján a főbb részvételt ösztönző tényezők közé tartoznak a gazdálkodók képzettségi szintje, a háztartásban élők száma, a földterület nagysága és a termelt növénykultúrák. Az oktatás valós szerepet tölt be abban, hogy a gazdálkodók magukénak érezzék a részvételi öntözésirányításra vonatkozó állami programokat. Az eredmények egyértelműen rámutatnak, hogy a gyakorlat általi tanulás nem kellően hatékony abban a tekintetben, hogy a gazdálkodók aktív szerepet vállaljanak az öntözésüzemeltetésben. A kapott eredmények a nagyobb háztartások pozitív hatását is igazolták a részvétellel kapcsolatban. Mindez kulcsfontosságú abból a szempontból, hogy a részvételi öntözésirányítás által elért pozitív eredmények így többszörösen fejthetik ki hatásukat. Azonban az eredmények rámutattak a fölterület nagyságának negatív hatására a részvételi öntözésirányítás szempontjából. Mivel a nagyobb területeken termelő gazdálkodók nagyobb valószínűséggel alkalmaznak szezonális munkásokat az öntözési feladatok elvégzésére, kevesebb közvetlen tapasztalatuk van az esetleges hatékonysági problémákkal kapcsolatban. A kutatás rámutatott, hogy a részvételen alapuló öntözésüzemeltetés csak akkor sikeres, ha a gazdálkodók személyesen vesznek részt a napi tevékenységekben.

Klaszterelemzést végeztünk annak érdekében, hogy a gazdálkodókat egymástól jól elhatárolt csoportokba soroljuk az öntözésirányításban való részvételük alapján. A klaszteranalízis négy szignifikánsan különböző csoportot eredményezett három részvételt mérő indikátor alapján (Gazdálkodói Részvételi Index, öntözési képzésben való részvétel és információs rendszerekhez való hozzáférés). A klaszterelemzést megerősítette a részvételi öntözésirányítás feltárt ösztönzőit két változó esetében. A csoportok között szignifikáns különbséget tapasztaltunk a gazdálkodók képzettségével és a termelésbe vont terület nagyságával kapcsolatban. Ezenkívül a négy klaszter statisztikailag különbözik a két újonnan bevezetett változó – bevétel és profit – esetében is. A kapott eredmények alapján ezek a változók valószínűsíthetően korrelációban vannak az GRI-vel. A klaszterelemzés tehát két fontos eredménnyel bír: i./ a gazdálkodói csoportok jellemzése a részvételük alapján, és ii./ a részvételi üzemeltetés teljesítménymutatóinak feltárása.

A részvételi öntözésirányítás gazdálkodókra gyakorolt hatását négy alternatív módszertan segítségével vizsgáltuk: átlagok különbsége, regressziós elemzés, becsült részvételi valószínűség szerinti párosítás és entropy balancing. A kísérleti terület adottságaiból kiindulva (többek közt elszigeteltség, a historikus adatok hiánya, a kísérlet költsége és a környezeti feltételek változékonysága), tényellentétes hatáselemzést alkalmaztunk kísérleti módszertan keretében. Az újszerű módszertant annak érdekében alkalmaztuk, hogy a részvételi üzemeltetés közvetlen hatását mérhetővé tegyük a gazdálkodók valós részvételi mutatója alapján. Ezért a gazdálkodók részvételét a Gazdálkodói Részvételi Index alkalmazásával mértük. A gazdálkodókra gyakorolt hatást a klaszterelemzés során meghatározott teljesítménymutatókhoz viszonyítottuk (bevétel és profit), kiegészítve a hozam változóval. Az eredmények alapján elmondható, hogy a részvételen alapuló öntözésirányítás pozitív és szignifikáns hatással van a teljesítményindikátorokra, ami alapján megállapítottuk, hogy a „résztvevő" gazdálkodói csoport jobb eredményeket ér el bevétel, profit és hozam tekintetében. Ezzel együtt bizonyítható, hogy a részvételen alapuló öntözésirányítás megfelelően szolgálja a fejlesztési programok és az integrált vízgazdálkodás átfogó célkitűzéseit.

A kutatás során az alábbi új tudományos értékű eredmények fogalmaztuk meg:

1. A tanulmány kiemelte a részvételen alapuló öntözéskezelés multidiszciplináris megközelítésének fontosságát. Egy szakmailag elfogadott teljesítményértékelésre megalkotott módszertant, a Rapid Appraisal Procedure-t (Gyors Értékelési Módszertan) alkalmaztuk az öntözésüzemeltetéshez köthető tevékenységek meghatározására, melyek ellátása három szervezeti egység közt oszlik meg: állam, vízitársulat és gazdálkodók. Az eredmények azt mutatták, hogy a rendszer teljesítményének elemzése elengedhetetlen az öntözésmenedzsment vízgazdálkodási és szervezeti hatásköreinek megállapításához, valamint hogy a hatáskörök átruházásának sikeressége túlmutat a mérnöki kérdéskörökön.
2. A kutatás rámutatott, hogy még a viszonylag homogén közösségek gazdálkodói is eltérő mértékben vesznek részt a menedzsmentben. Az eredmények alapján bizonyítást nyert, hogy az oktatás és a háztartások száma pozitívan és szignifikánsan hat a menedzsmentben való részvételre. Negatív hatások a földterület mérete kapcsán tapasztalhatók, ahol a nagyobb birtokterület csökkenti a részvételi hajlandóságot. Ez az eredmény azt bizonyítja, hogy az üzemeltetéssel kapcsolatos felelősségi körök átruházhatósága kérdésessé válik megfelelő képzettség nélkül, illetve kisebb háztartások esetében. A földterület méretének negatív hatása pedig arra mutat rá, hogy a gazdálkodók kevésbé válnak elkötelezetté amennyiben nincs közvetlen és személyes tapasztalatuk az öntözési anomáliák kapcsolatban.
3. A kutatás sajátos módszertant alkalmazott a gazdálkodók öntözésüzemeltetésben való részvételének mérésére. A részvétel

egyéni szintű mérése lehetővé tette a hatáselemzést „résztvevők – nem résztvevők” típusú becslés keretén belül. A későbbiekben erre alapozott robusztus módszertanok így megoldást találtak a korábbi hatástanulmányok hiányosságaira, név szerint az idő és földrajzi korlátokre, a kutatás időszakára jellemző változékony körülményekre és ezek hatásaira, valamint a gazdálkodók eltérő adottságaira.

4. A részvételen alapuló öntözésüzemeltetés ösztönzőinek feltárása során a kutatás olyan teljesítménymutatókat azonosított, amelyek közvetlenül mérik a felelősségi körök átruházásából fakadó hasznokat. Az eddig széles körben alkalmazott rendszerhatékonyság és a költségmegtérülés teljesítménymutatók helyett olyan mutatókat alkalmaztunk, melyek közvetlenül hozzájárulnak a gazdálkodók életszínvonalához. A kutatás ezen sajátossága kiemelt fontossággal bír a szegénység enyhítését célzó fejlesztési politikákban.
5. A kutatás tényellentétes hatáselemzést alkalmazott a részvételen alapuló öntözésüzemeltetés hatásainak mérésére. Ez megközelítés alkalmasnak bizonyult a hasznok egyéni szintű mérésére. Az ilyen típus módszertan új perspektívát szolgál a részvételen alapuló öntözésüzemeltetéshez hasonló komplex fejlesztési programok. A kutatás igazolta a gazdálkodókra gyakorolt pozitív hatást, és ezáltal alátámasztotta a részvételi öntözésüzemeltetés fejlesztési programokba való beágyazhatóságát.

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Food and Agriculture Organization and Agricultural Water in Africa: Strengthening agricultural water efficiency and productivity at African and global level workshop, Rome, Italy, 12-13.12.2019: National Agricultural Water Policy Sector in Uganda

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14.CURRICULUM VITAE

Éva Pék (13.06.1988, Nyíregyháza, Hungary)

Éva Pék was born in Nyíregyháza, Hungary. She received the degree "Rural Development Engineering" from University of Debrecen in 2014. She completed a semester in University of Wageningen, where she was a research associate working on environmental economics. She applied for and has been accepted into the Doctoral School of Management and Organizational Science , University of Kaposvár in 2015. She completed her comprehensive examination in June 2020. During her PhD studies, she worked as an associate in University of Cordoba, where she was tasked with water economics and water productivity related research in developing countries. Ms Pek works currently as water management specialist in the Land and Water Division of Food and Agriculture Organization. Her current research interests include water economics, participatory approaches, water policy, water resource monitoring and management and drought management.

15.ANNEX

Survey design

I. Information

Name: […….]

Gender: […….]

Location of farming (Division): […….]

Produced crop/s: […….]

II. Characteristics

Education level (primary=1, secondary=2, advanced=3, university=4): […….]

Age (15-25=1, 25-35=2, 35-45=3, 45-55=4, above 55=5):

Land size (acre):

Number of members of household: […….]

Membership of Cooperative/WUA/extension service: (No=0, Yes=1): […….]

Attended in irrigation training/course (No=0, Yes=1): […….]

Frequent experience of water shortage or waterlogging (No=0, Yes=1): […….]

Frequent experience of failing production (No=0, Yes=1): […….]

Access to information system on production and water use (No=0, Yes=1): […….]

Average yield of the crop/s (tons per acre): […….]

Average revenue of the crop/s (1000 UGX per acre): […….]

Average production cost of the crop/s (1000 UGX per acre): […….]

Average profit per acre (1000 UGX per acre): […….]

III. Participation in management measures

Water discharge measurement (No=0, Yes=1): […….]

Visiting other schemes (No=0, Yes=1): […….]

Cooperation with other farmers to re-distribute water (No=0, Yes=1): […….]

Regular participation in irrigation training (No=0, Yes=1): […….]

Other water-management techniques (No=0, Yes=1): […….]

Attending meeting in irrigation turn planning (No=0, Yes=1): […….]

Regular participation in extension service related to irrigation practices (No=0, Yes=1): […….]

Adjustment of water supply to observed crop demand (No=0, Yes=1): […….]

Weeding, bushing, profiling tertiary and quaternary canals (No=0, Yes=1): […….]

Regular manual work on the irrigation infrastructure (No=0, Yes=1): […….]

Consultation with WUA officers about maintenance (No=0, Yes=1): […….]

Private investment on the irrigation infrastructure (No=0, Yes=1): […….]

Contribution (in-kind or cash) to canal maintenance (No=0, Yes=1): […….]

Regular payment of water fee (No=0, Yes=1): […….]