Critical assessment and addressed challenges in deploying innovative technologies in small-scale irrigation scheme in Uganda

Session II.
Improving water-efficient irrigation: Prospects and difficulties of innovative technologies and practices in agricultural water management

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PART II.

Critical assessment and addressed challenges in deploying innovative technologies in small-scale irrigation scheme in Uganda

OUTLINE

The differences in applied techniques (flexibility, investment cost, accuracy)

Compiled dataset

Comparative analysis of measurement time-series

Challenges of deploying technology for discharge measurement


in Mubuku irrigation scheme, Uganda


LSPIV measurement
low-cost, high-tech, non-traditional, people-centered observations and monitoring


Weir measurement
traditional, easy to construct, highly accurate overflow structure

The differences in applied techniques – figures after the second measurement campaign

Traditional measurement system

6 measurement sites

6 installed weir

3 measurement campaigns

159.1 l/s annual mean discharge

ca. **4.95 million m3/year** water supply

+/- **5** % error range

Non-traditional measurement system

13 measurement sites

6 relocated sites

Real time measurement values

92.1 l/s annual mean discharge

ca. **2.92 million m3/year** water supply

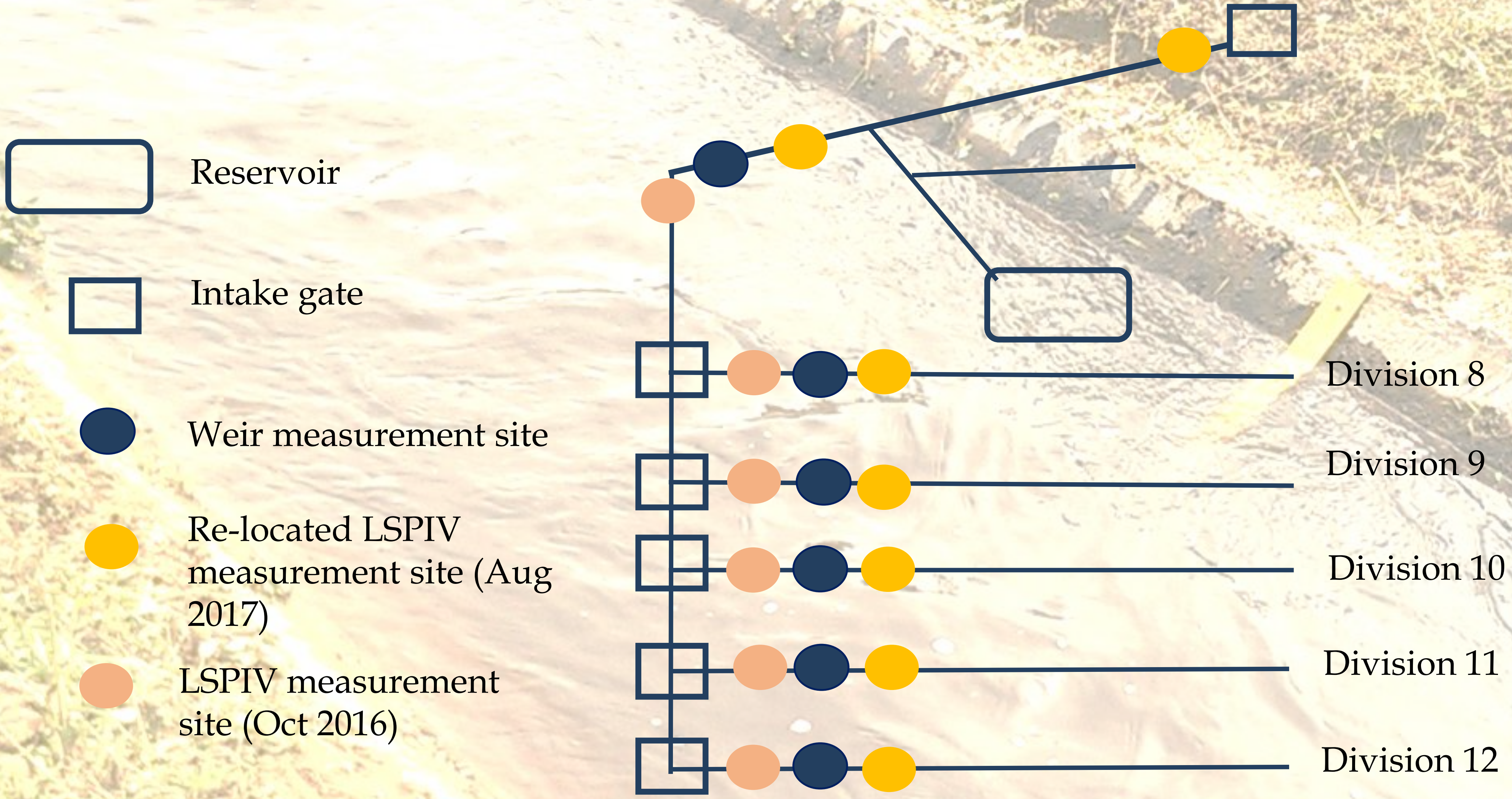
relative error range:

21.3% of data within ± 5% rel. error

42.1% of data within ±10% rel. error

75.1% of data within ±20% rel. error

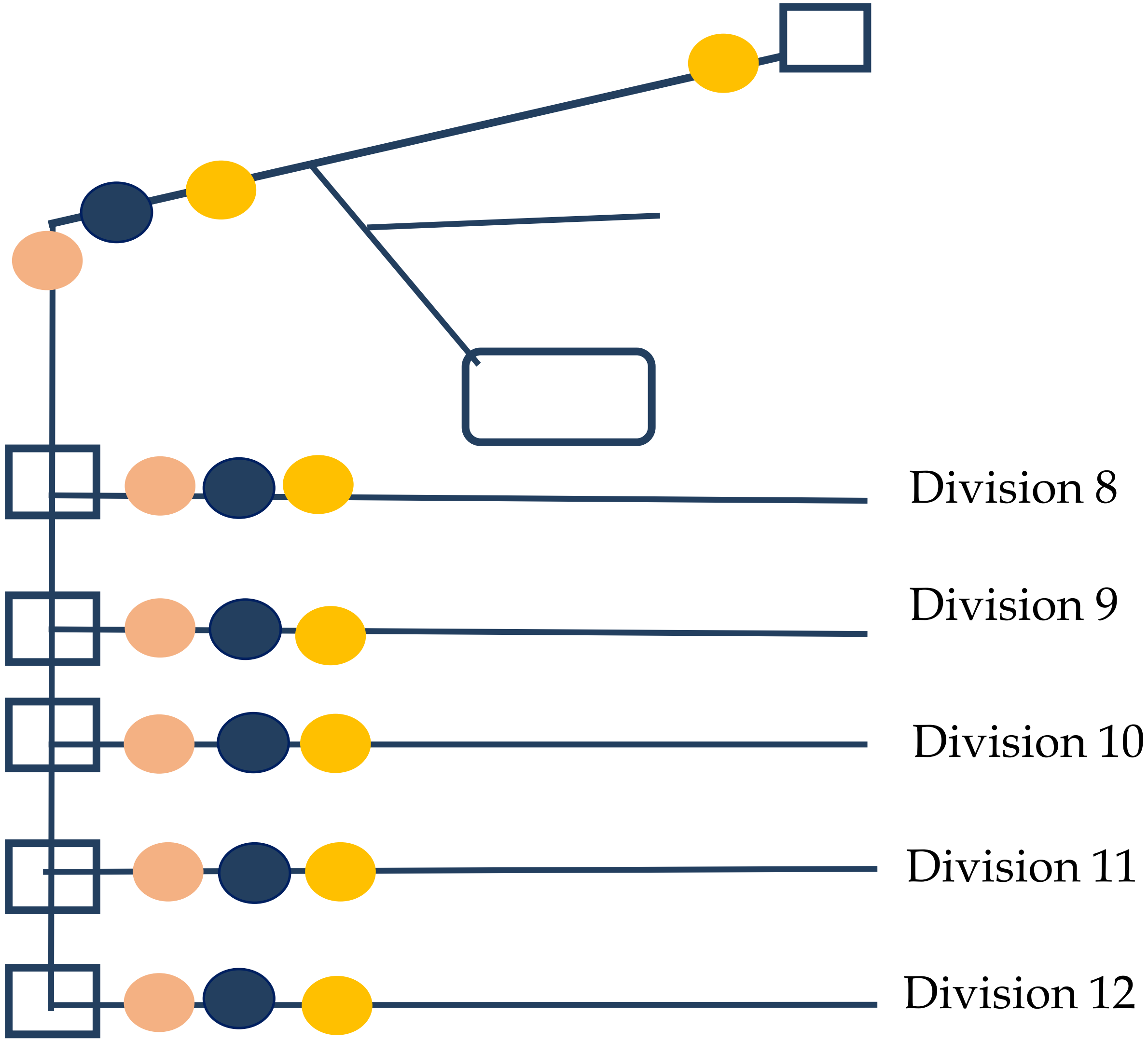
The differences in applied techniques



Comparative analysis of measurement time-series

Measurement changes (August 2018)

- LSPIV sites relocated downstream of the weir
- Devices settings are changed to higher resolution
- Continuous data uploading and transmission online
- Measurement calibration and validation based on weir time-series
- Application upload released:
    - Deliver error estimates
    - Higher Android compatibility



The differences in applied techniques - flexibility

Traditional measurement system

Unscheduled gate opening in upstream → Measurement disturbances → Fluctuating water level →  → Repeated validation process

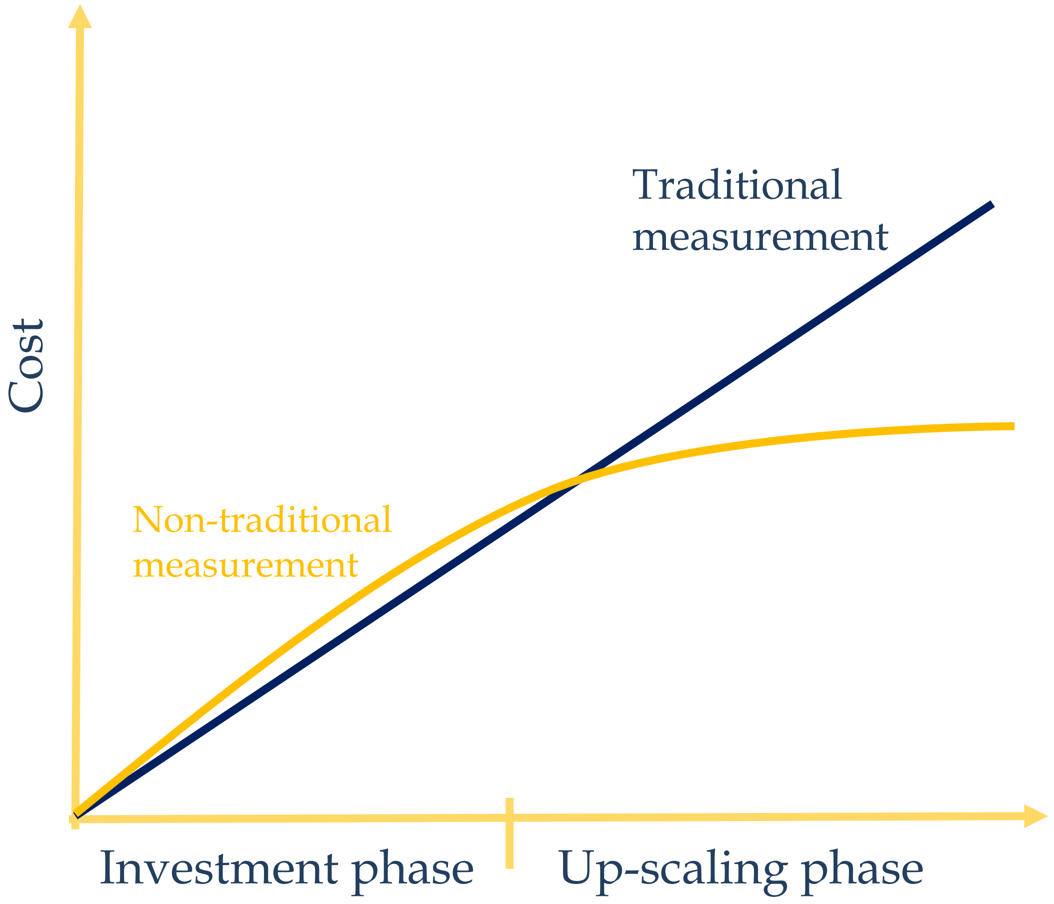
Non-traditional measurement system

Backwater effect due to weir installation →  → Need of site relocation → Inappropriate measurement setting → Repeated validation process

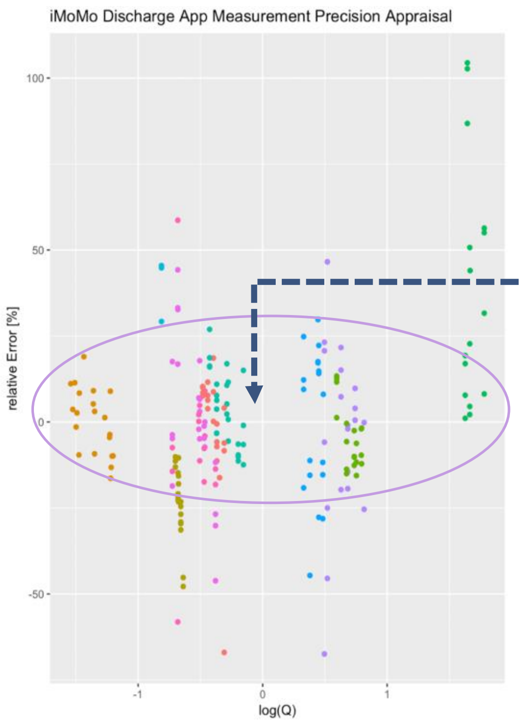
The differences in applied techniques – investment cost

Investment phase → Maintenance phase

	Weir	LSPIV technology
Human resources including "soft" costs (training)	16 280	16 280
Construction or other equipment (construction, service rent etc.)	708	2 700
Devices (flow meter, mobile phones, etc.)	1 889	1 140
Total	**18 877**	**20 120**

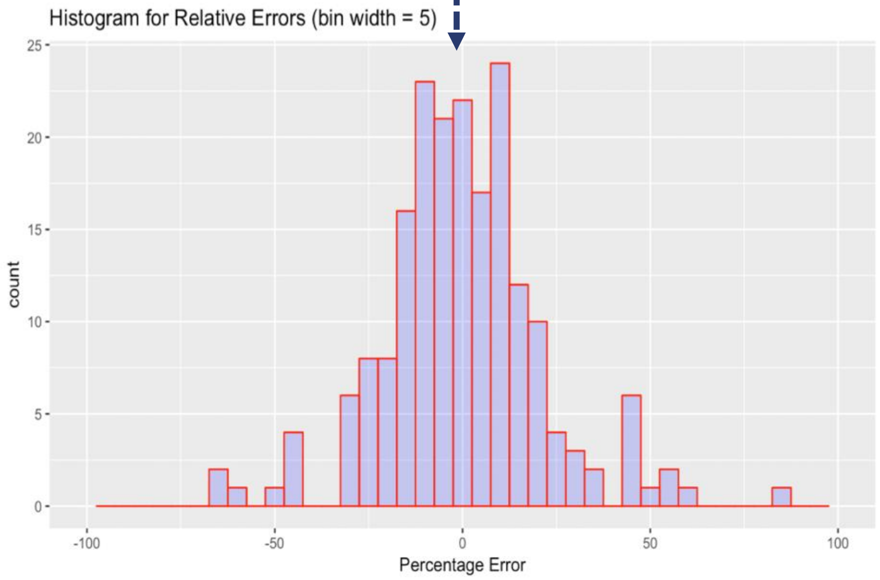


The differences in applied techniques – Accuracy



LSPIV expected accuracy:

21.3% of data within ± 5% rel. error
42.1% of data within ±10% rel. error
75.1% of data within ±20% rel. error

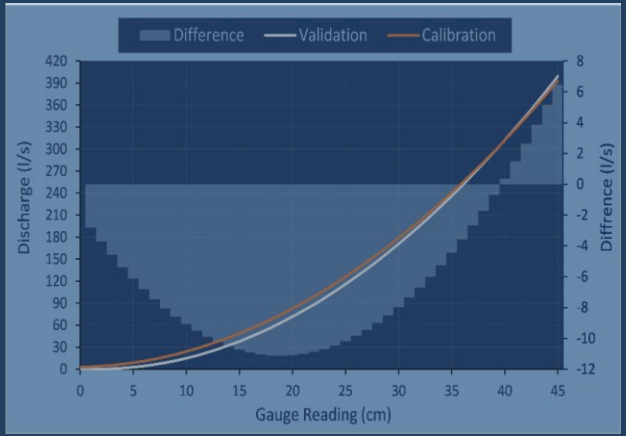


Accuracy factors:

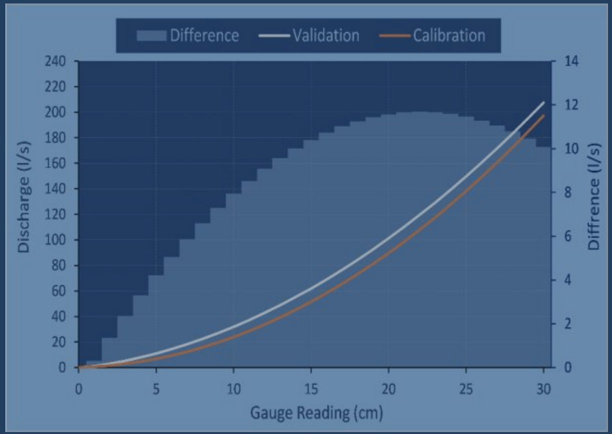
- Not all surface wave patterns travel with the actual velocity of the water
- Effect of canal walls visible in slow moving patterns on the surface (undulating waves)
- Velocity profile plot shows fast (actual water velocity) and slow moving signals (undulating waves)
- If slow moving features are present, this can lead to underestimation of discharge
- Surface patterns/tracers moving to the side of the canal results 0 value in the cross-correlation, thus decreasing the overall average

The differences in applied techniques – Accuracy

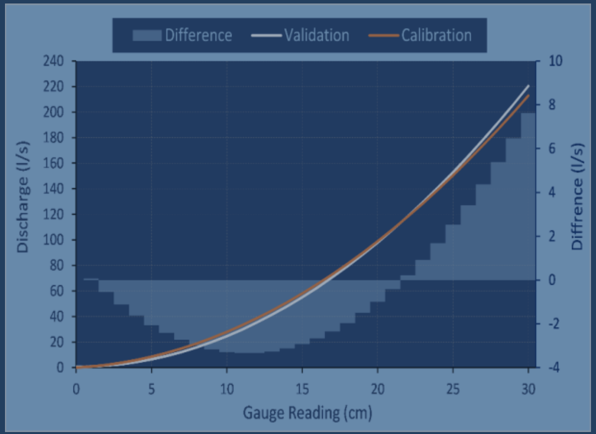
Weir expected accuracy



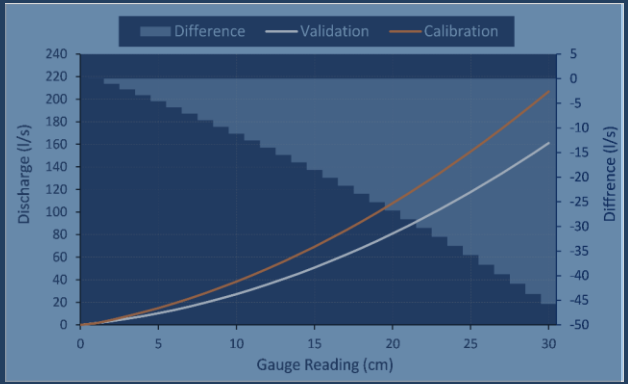
Main Canal within +/- 5%



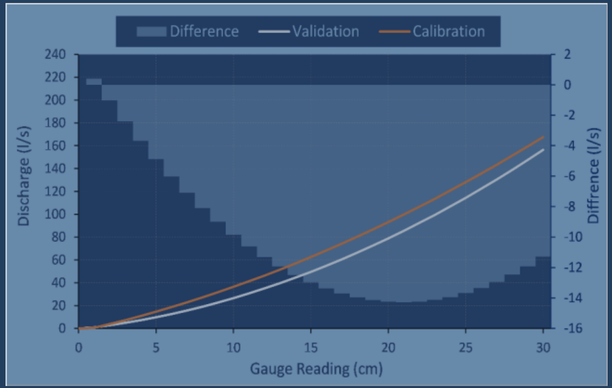
Division 8 within +/- 5%



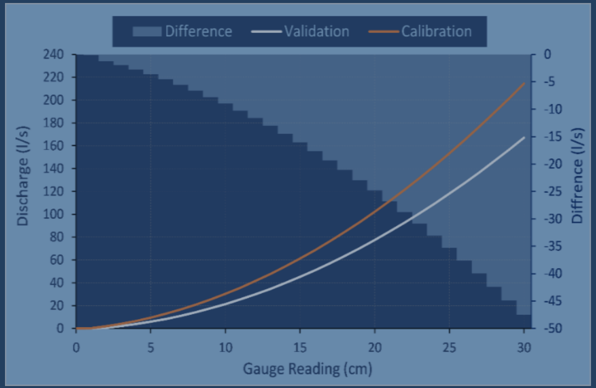
Division 9 within +/- 5%



Division 10 – lower accuracy



Division 11 within +/- 5%



Division 12 – lower accuracy

Compiled dataset

Traditional measurement system

12/05/2017-31/12/2017	No of observation	No of missing values
Main Canal	176	58
D8	176	58
D9	176	58
D10	175	59
D11	176	58
D12	176	58

Non-traditional measurement system

25/10/2016-31/12/2017	No of observation	No of missing values
Main Canal	291	239
D8	277	246
D9	260	257
D10	264	252
D11	277	249
D12	287	238

Compiled dataset – LSPIV

Intake gate

Main canal

Division 8

Division 9

Division 10

Division 11

Division 12

Influencing factors:

- Wet season, sufficient rainfall
- Environmental and domestic reasons
- System shut-down
- Physical intervention (construction or other obstacle)
- Accuracy disturbing conditions (no light, insufficient tracers, not steady flow, backwater effect)
- Crowd-sender's availability
- Inconsistent dataset, data error, synchronization failed

Compiled dataset

Traditional measurement system

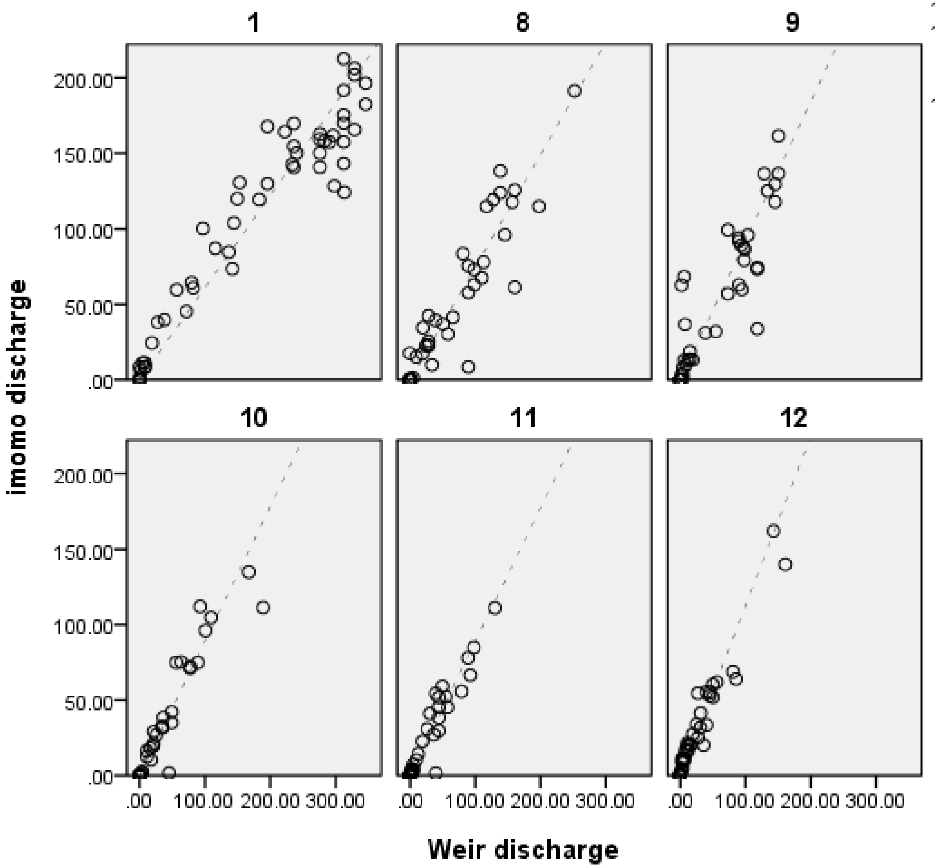
- Reported measurement disturbance
- Mostly continuous measurement in weekly (6 days) step
- Irrigation and non-irrigation days are not differentiated
- Measurement time is not available
- Significant data gap in October and November
- Period of double measurement

Non-traditional measurement system

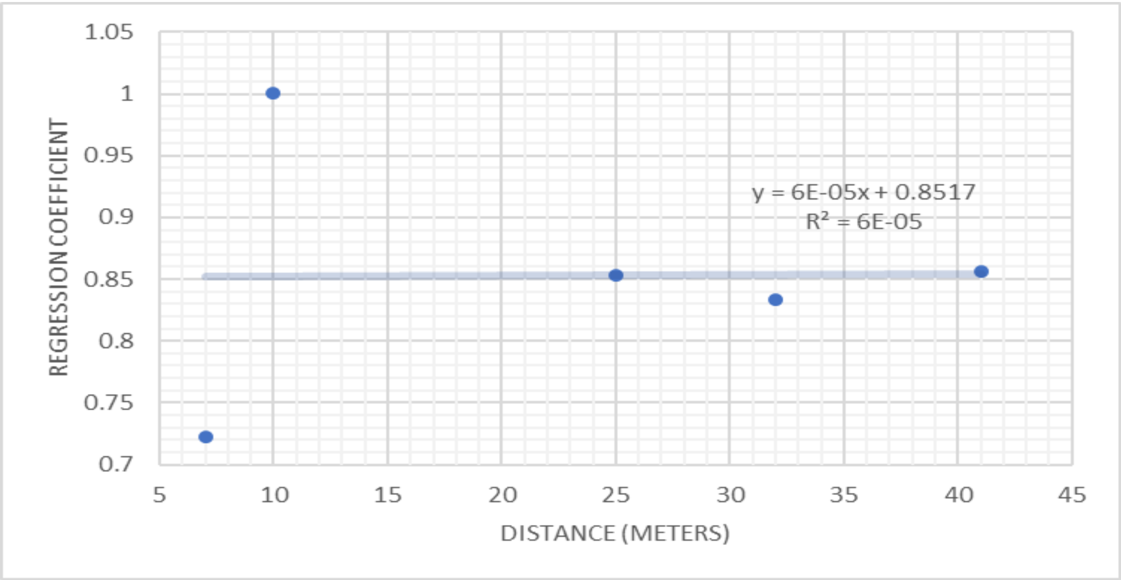
- Reported measurement disturbance
- Random measurement in weekly (7 days) step
- Irrigation and non-irrigation days are not differentiated
- Exact measurement timing
- Significant data gap in August, October, November
- Random double measurement

Comparative analysis of measurement time-series

Relation with distance



11R² Linear = 0.918
10R² Linear = 0.877
8R² Linear = 0.870
1R² Linear = 0.884
12R² Linear = 0.893
9R² Linear = 0.771



No relation between the distance of the LSPIV measurement site from the weir and the accuracy of measurement (slope of linear regression)

Comparative analysis of measurement time-series

Consistency analysis of
i./ weir measurement, ii./ LSPIV in old site and iii./ LSPIV in relocated site

Trend analysis: permanence of the flow characteristics

ANOVA and non-parametric tests: difference between the time series

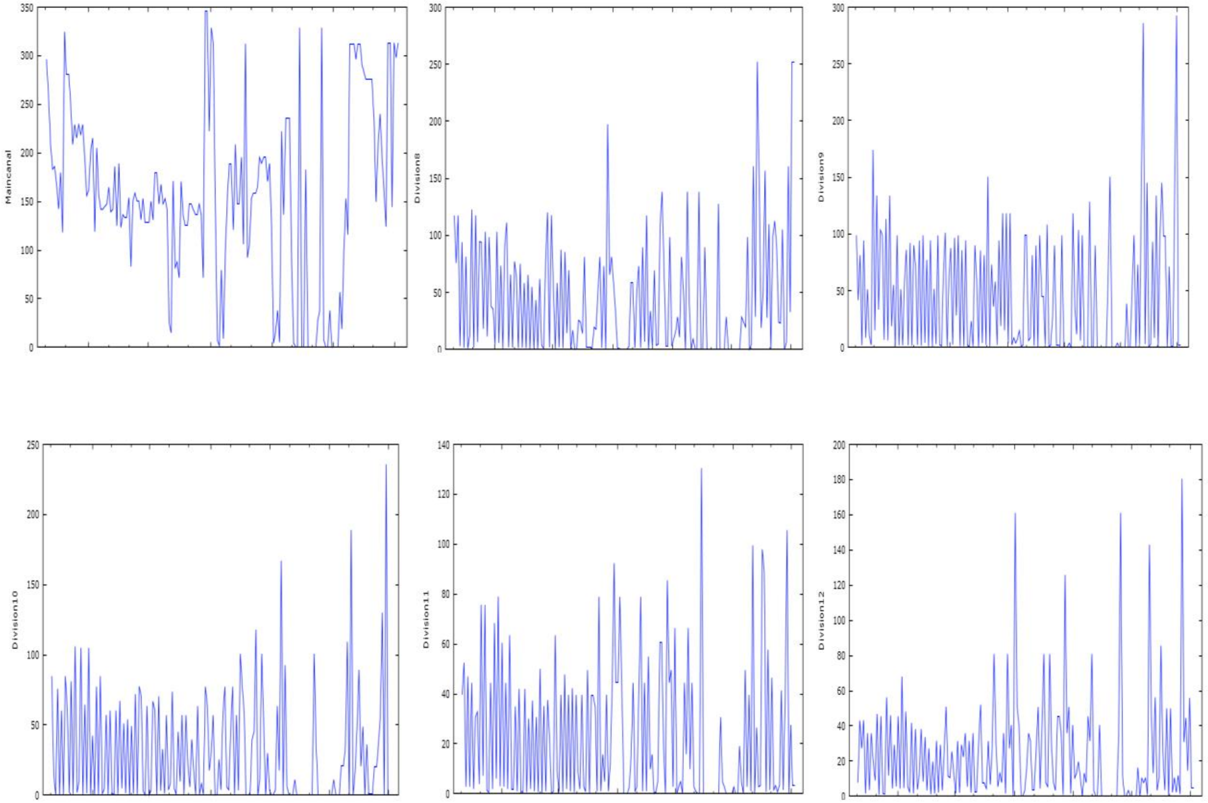
METHODOLOGY

Downstream inferiority

Distribution of relative errors

Comparative analysis of measurement time-series

1. Summary statistics

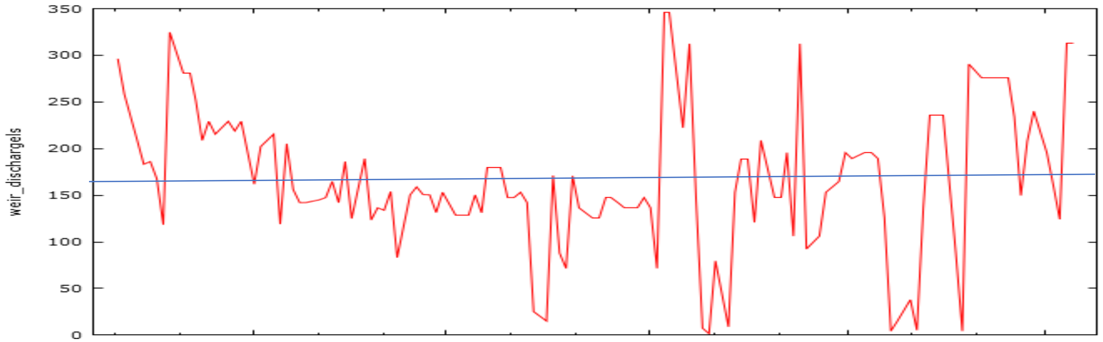


Period of May 2017 – December 2017

	Weir	LSPIV old site	LSPIV new site
Absolute difference in mean value of upstream and downstream	**21**	**15**	**21**
Absolute difference in max value of upstream and downstream	**120**	**126**	**80**

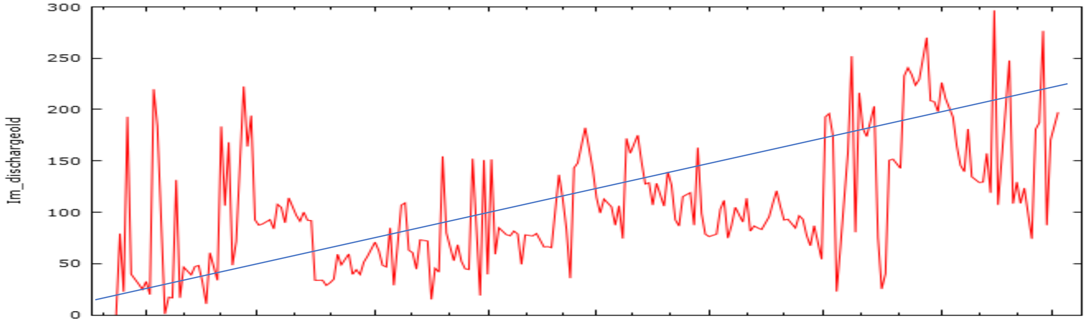
Comparative analysis of measurement time-series

2. Stationarity visual analysis: assuming no trend or periodicity in time series



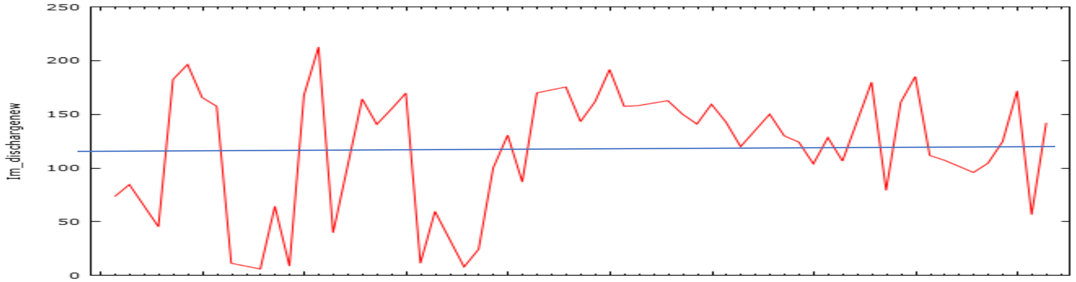
Weir: no trend identified
OLS: not significant relation between time and discharge values

stationary



iMoMo old site: trend identified
OLS: significant relation between time and discharge values

non-stationary



iMoMo new site: no trend identified
OLS: not significant relation between time and discharge values

stationary

Comparative analysis of measurement time-series

2. Stationarity visual analysis: assuming that the time-series are stationary or there is no unit root

Traditional measurement system

ADF test	
Specification 1	Not-stationary
Specification 2	Not-stationary
Specification 3	Not-stationary
KPSS test	Stationary

The stationarity assumption is accepted at the weir measurement

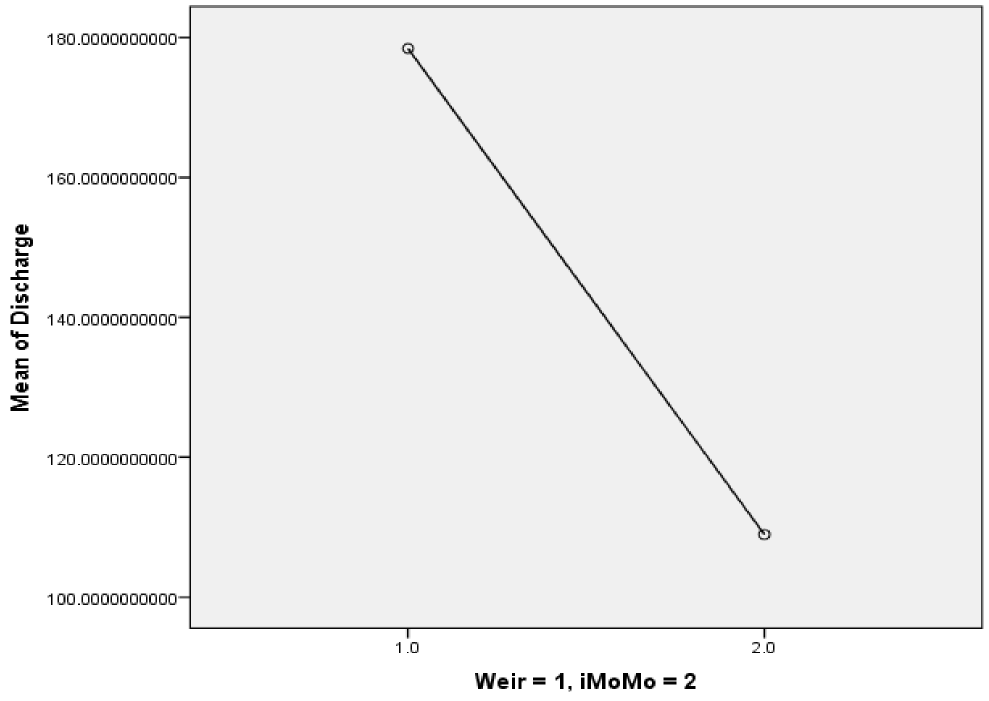
Non-traditional measurement system

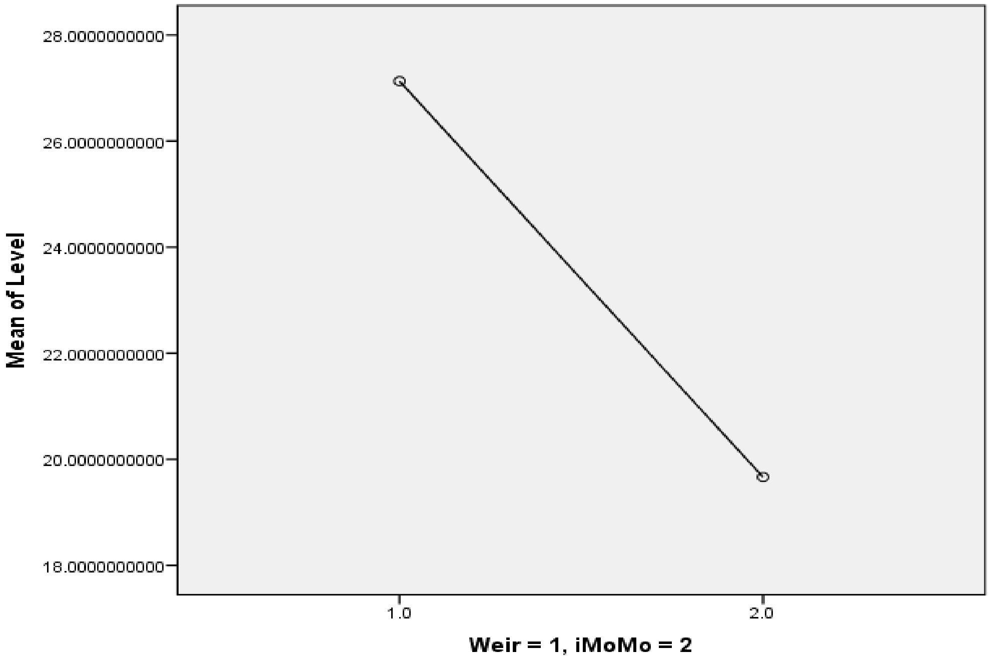
	old site	new site
ADF test		
Specification 1	Not-stationary	Stationary
Specification 2	Not-stationary	Not-stationary
Specification 3	Not-stationary	
KPSS test	Not-stationary	Stationary

The stationarity is significantly improved after the relocation

Comparative analysis of measurement time-series

3. Test for difference: ANOVA





Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
Discharge	38.502	1	104	.000
Level	9.556	1	104	.003

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Discharge	Between Groups	127921.373	1	127921.373	12.910	.001
	Within Groups	1030480.267	104	9908.464		
	Total	1158401.640	105			
Level	Between Groups	1476.409	1	1476.409	10.277	.002
	Within Groups	14940.914	104	143.663		
	Total	16417.323	105			

Comparative analysis of measurement time-series

3. Test for difference: ANOVA

Old iMoMo site

Main Canal and Division 9: both discharge and level are significantly different

Division 8: discharges have a very similar average and the level measurements are at the limit of acceptability

Division 10, Division 11 and Division 12: the values for the average water levels are not similar

New iMoMo site

Main Canal: both discharge and level are significantly different

Division 9 and Division 12: average discharge values are similar, level distributions are different

Division 8, Division 10, and Division 11: overall similarity of the means for the two distributions

Comparative analysis of measurement time-series

3. Test for difference: non-parametric test

Old iMoMo site

Division	Measurement	Wald-Wolfowitz Runs Test	Median Test	Test of Extreme Reaction	Kruskal-Wallis Test	Kolmogorov-Smirnov Test
Main Canal	Discharge	0.000	0.000	0.995	0.000	0.000
	Level	0.904	0.004	0.187	0.000	0.000
Division 8	Discharge	0.887	0.88	0.694	0.380	0.387
	Level	0.952	0.651	0.001	0.039	0.05
Division 9	Discharge	0.037	0.144	0.895	0.127	0.028
	Level	0.000	0.006	0.000	0.000	0.000
Division 10	Discharge	0.041	1.000	0.406	0.686	0.009
	Level	0.006	0.018	0.000	0.000	0.000
Division 11	Discharge	0.025	0.938	0.958	0.321	0.172
	Level	0.562	0.535	0.185	0.001	0.000
Division 12	Discharge	0.177	0.877	0.598	0.665	0.591
	Level	0.139	0.002	0.247	0.000	0.000

Discharge distributions are significantly different in three locations!

Water level distributions are significantly different in five locations!

Medians and peaks of the distributions cannot always be considered as similar

Confirms ANOVA results

Comparative analysis of measurement time-series

3. Test for difference : non-parametric test

New iMoMo site

Division	Measurement	Wald-Wolfowitz Runs Test	Median Test	Test of Extreme Reaction	Kruskal-Wallis test	Kolmogorov-Smirnov Test
Main Canal	Discharge	0.006	0.052	0.944	0.004	0.000
	Level	0.165	0.007	0.944	0.000	0.000
Division 8	Discharge	0.982	0.835	0.129	0.489	0.49
	Level	1.000	0.835	0.011	0.571	0.949
Division 9	Discharge	0.867	1	0.631	0.707	0.416
	Level	0.187	0.269	0.001	0.010	0.017
Division 10	Discharge	0.966	1.000	0.057	0.808	1.000
	Level	0.966	0.821	0.057	0.667	0.906
Division 11	Discharge	0.933	0.831	0.758	0.764	0.993
	Level	0.999	0.830	0.867	0.722	0.461
Division 12	Discharge	0.500	0.377	0.631	0.300	0.416
	Level	0.813	0.015	0.126	0.003	0.004

Discharge distributions are significantly different only at main canal!

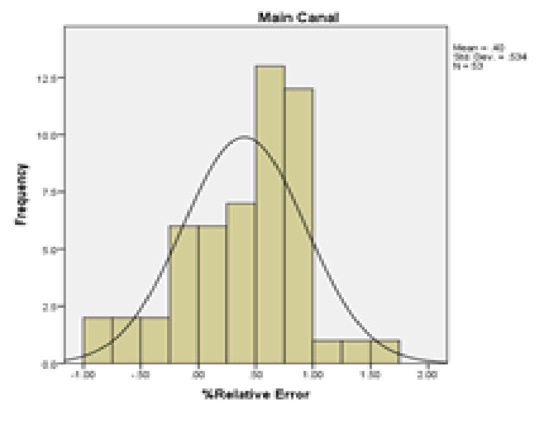
Water level distributions are significantly different in three locations!

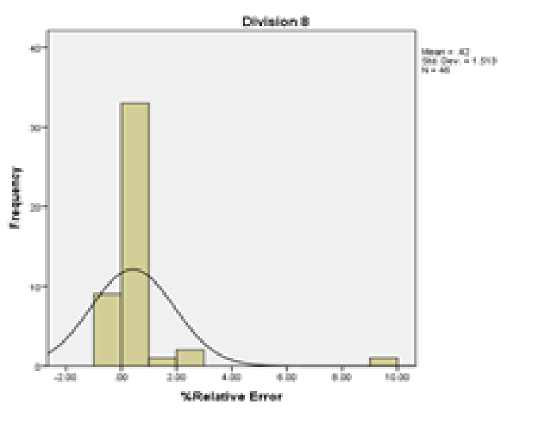
Improved similarity between the median and peaks of the distributions

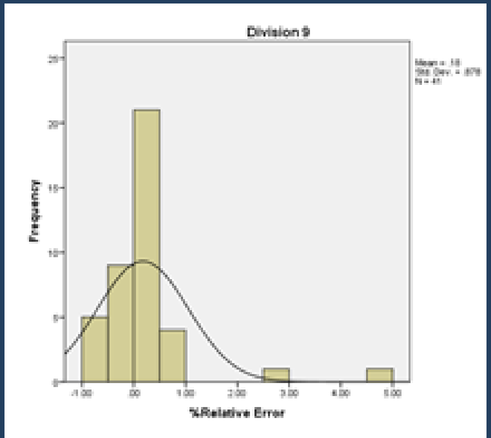
Confirms ANOVA results

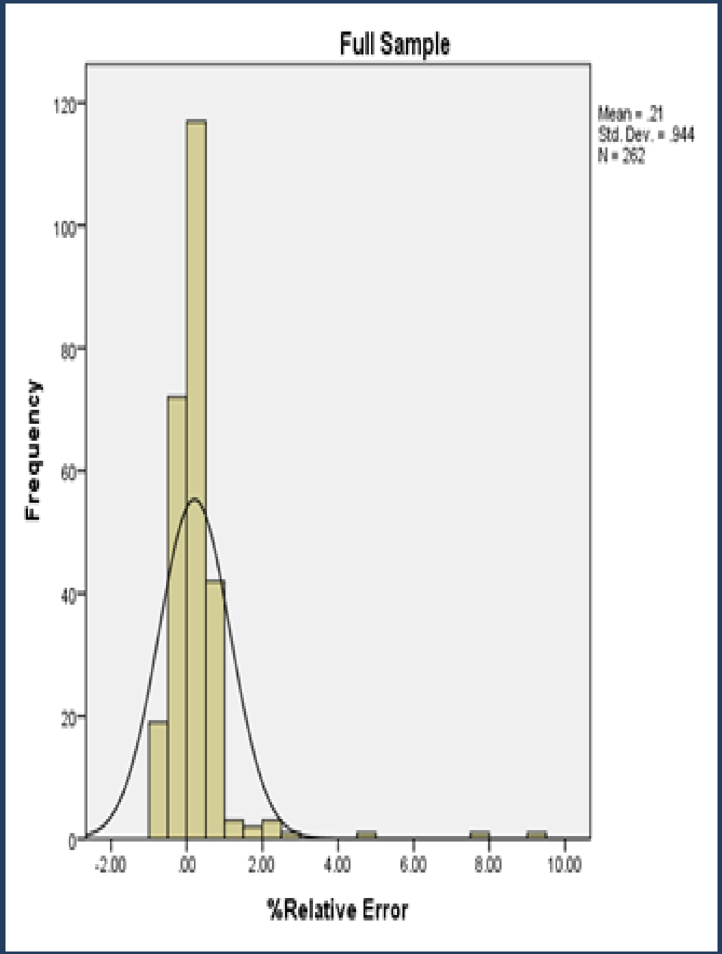
Comparative analysis of measurement time-series

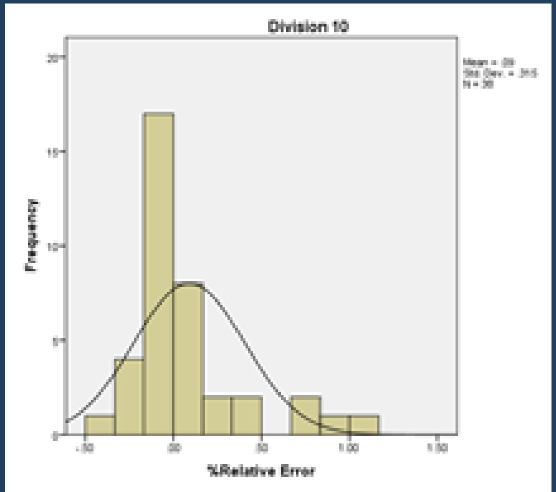
4. Distribution of relative errors

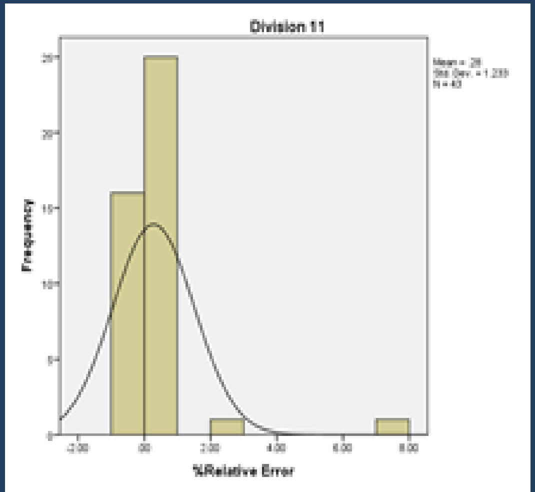


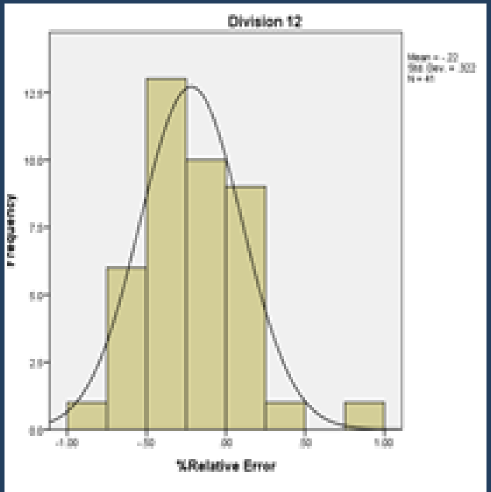












Comparative analysis of measurement time-series

4. Distribution of relative errors

Site	± 20 percent relative error range	± 10 percent relative error range
Main Canal	18.9	15.1
Division 8	43.5	37.0
Division 9	53.7	31.7
Division 10	71.1	55.3
Division 11	60.5	27.9
Division 12	39.0	22.0

Most of the sites show between **40 and 70%** of the measurements **within the ± 20 %** relative error range.

Between **22 and 55%** of the measurements are **within the ± 10 %** relative error range.

Better results for the relocated iMoMo site

Challenges of deploying technology for discharge measurement

Expected accuracy

Installation must consider all physical factors which influences the technology's accuracy

There must be an evidence-based understanding on acceptable range of errors

Flexibility of technology, for example ease of relocation, helps mitigate the expected errors

Non-contact discharge measurement technology enables to acquire data at lower level, such as field level, therefore technology means an option directly for farmers

Technology deployment can not rely on the assumption of optimal conditions (such as farmers behaviour), therefore it must provide solution in sub-optimal conditions

Challenges of deploying technology for discharge measurement

Relation of cost-efficiency and scalability

Technology must be cost efficient, and both hard and soft expenses must be considered in investment and maintenance phase

The rigidity of fixed structures results growing expenses while extending the system

Ease of relocation results diminishing curve of expenses while extending the system

Deployment must consider the optimal size of operating area and the possible extent of scalability

Challenges of deploying technology for discharge measurement

Data interpretation

Data acquisition is not sufficient to translate it into management rule, clear interpretation of data is required to build solid ground for understanding

Data collection must be based on understanding the obtained data, therefore protocol must be launched for users

Technology must be available and easy-to-understand for broader stakeholder group, such as farmers' communities, not only to deliver know-how, but ensure the long-term use

Farmers are willing to learn new technologies most likely multiplication effect of training among themselves – learning from each other


Our team is growing larger and working on scaling-out
and scaling-up the technology for farmers