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Resilience of Farmers at Water Shortage Situations in Minor Irrigation Systems: A Case Study in Kurunegala District, Sri Lanka

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ABSTRACT: *Farmers in Minor Irrigation Systems (MIS) experience many difficulties due to severe seasonal or year-round absolute water scarcity that affects their livelihoods. In order to address this problem, the resilience of the vulnerable communities needs to be enhanced through smart investments and appropriate adaptation strategies. Since there is no well-established method for assessing the resilience of the farmers in MIS, this study was aimed to develop a framework and prospective methodology to assess resilience and factors determining the resilience to shocks and stresses of MIS. A structured questionnaire survey was carried out among 188 households belong to eight farmer organizations under 16 MIS located in three Agrarian Service Divisions in the* IL_3 *agro-ecological region in Kurunegala District. The resilience of farming was measured using adaptive capacity or the risk management strategies used at household levels related to farming practices using 20 indicators. Analysis of factors was performed with the principle component method and rotated (from Varimax with Kaiser Normalization technique) factor loadings were extracted to compute resilience index. Using the empirical equation derived from the study, the resilience of MIS was quantitatively determined. The results showed that there is an adequate space to enhance the resilience of farming in MIS by introducing and adapting various risk management strategies. It appears that capacity of the tank, accessibility of services and the trust of farmers both on farmer organizations and the agency officials are some of the key factors which govern the resilience of farming in MIS.*

Keywords: *Livelihood, minor irrigation system, resilience, risk management, water scarcity*

INTRODUCTION

Village tanks, which provide irrigation water to command areas of less than 80 ha are classified as Minor Irrigation Systems (MIS) and have historically been built to fulfill food security needs of successive generations under water shortage conditions mainly in the Dry and Intermediate zones of Sri Lanka (Siriweera, 2002). The role of the irrigation sector has now become more important than ever before, because of the increasing population, high proportion of people living in rural areas and the large numbers of people dependent on agriculture for their livelihoods (IWMI, 2006). About two million farmer families or 65% of rural households are engaging in irrigated paddy farming as their main occupation (Shantha and Asan, 2014). Paddy, the main irrigated crop, is grown on nearly 730,000 ha of land of

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which 170,000 ha is grown under medium and MIS (Shantha and Asan, 2014). Many factors, which include technical, social and economic and governance issues currently challenge sustainability of the MIS (Thilakasiri, 2015; Wijekoon *et al.*, 2016; Kumara *et al.*, 2017).

Sustainability of agriculture is centered on concepts of both resilience (the capacity of systems to buffer the shocks and stresses) and persistence (the capacity of systems to continue over long periods) and addresses many wider economic, social and environmental outcomes (Pretty, 2008). The Intergovernmental Panel on Climate Change (IPCC) defines resilience as, "the ability of a system and its component parts to anticipate, absorb, accommodate or recover from the effects of a hazardous event in a timely and efficient manner, through ensuring the preservation, restoration or improvement of its essential basic structures and functions" (IPCC, 2012).

The water sector, including irrigated agriculture is by nature prone to risks and uncertainties of various aspects such as biophysical, abiotic, climatic, environmental, biotic (pests, diseases), economic and price-related risks, and political instability. Many of these risks have a climatic component and most of them will be affected by climate change (CC), either in intensity, scope or frequency. Depending on household or system vulnerability, the system will be more or less affected by the same shock. Recovery from shocks and stresses of a system depend on its level of resilience (Gitz and Meybeck, 2012).

A resilient agriculture is one that meets both food and development needs over both short and long-terms, from local to global scales, without destabilizing the earth system. The goal of the resilient agriculture is to enable a system to respond to changing conditions, so that, there are minimal losses to the system and maintain socio-ecological system stability. A more resilient agriculture will need to be persistent, adaptive, and transformative at the shocks and stresses in time with a broader set of mechanisms, such as the social networks, governance, and leaderships to meet the immediate needs of people (Vallée, 2008).

Problem identification and justification

Increasing water scarcity is one of the major global challenges today (Jacobson *et al.*, 2013). It is estimated that by 2025, most of the districts in the Dry and Intermediate zones of Sri Lanka will face severe seasonal or year-round absolute water scarcity at the current level of irrigation efficiency (Amarasinghe *et al.*, 1999). In *Yala* or minor season, 60% of lands under MIS are not cultivated due to water scarcity or shortage. It is known that rain fed agriculture followed by minor irrigation would likely be the most vulnerable and first casualty of impacts of CC in the agriculture sector (Aheeyar, 2015). With the changes in the eco-system and socio-economic conditions, farmers in MIS experience many difficulties that affect their livelihood. In order to address this problem in Sri Lanka, it is recommended to concentrate on smart investments and adaptation interventions (Bronzoni, 2015), to create "resilience" to water scarcity as well as CC among vulnerable groups while addressing "current development goals". However, the limitation is that there is no proper and well- established performance evaluation method for assessing the resilience of irrigated agricultural systems.

Therefore, this study was conducted to provide a framework and prospective methodology for assessing resilience and determine the outcomes of institutions aimed at enhancing resilience to shocks and stresses of MIS. In an effort to ground the conceptual and technical discussions of resilience, the study has also aimed to identify key challenges to achieve resilience and describes necessary steps for moving the resilience agenda forward in the MIS.

MATERIALS AND METHODS

Study area

This study was conducted in three ASDs, namely Kumbukgate, Kobeigane and Rasnayakapura in IL_3 agro-ecological region in Kurunegala district (7°45′N 80°15′E) in North Western Province of Sri Lanka (Figure 1). This agro-ecological region lies in the western half of the island and has mild drought conditions during *Maha* season due to the relatively low contribution of rains from the northeast monsoon. When rainfall during March is ineffective, it falls under the category of an area prone to severe drought conditions during *Yala* season (Chithranayana and Punyawardena, 2008).

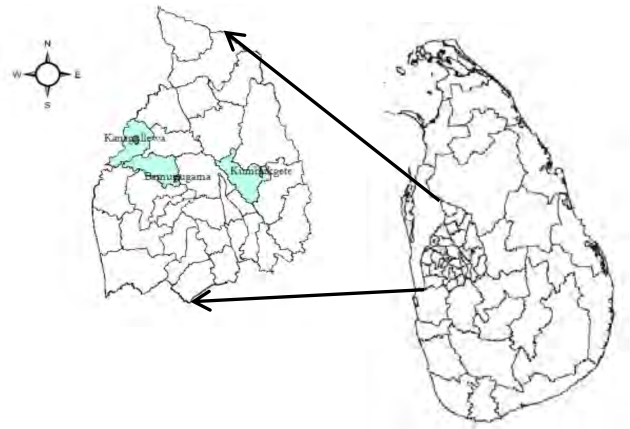

Figure 1. Study areas

Framework to assess resilience to farming in MIS

The resilience of a system to shocks and stresses depends on the exposure, sensitivity and adaptive capacity of the system (Frankenberger *et al.*, 2012). In that, exposure and sensitivity depend on the frequency of disasters and environmental conditions. Adaptive capacity can be managed by implementing different risk management strategies within the system. Therefore, the resilience of farming is measured using adaptive capacity or the risk management strategies used in their households related to farming practices. Previous studies conducted to assess the vulnerability and resilience to CC induced shocks includes socioeconomic and political status of individuals or social groups (Tesso *et al.*, 2012). Resilience is delineated into three major categories such as farming assets (including labor, land, water and accessibility of inputs and services related to farming), farming strategies (including different farming techniques) and governance or institutional support as shown in Figure 2.

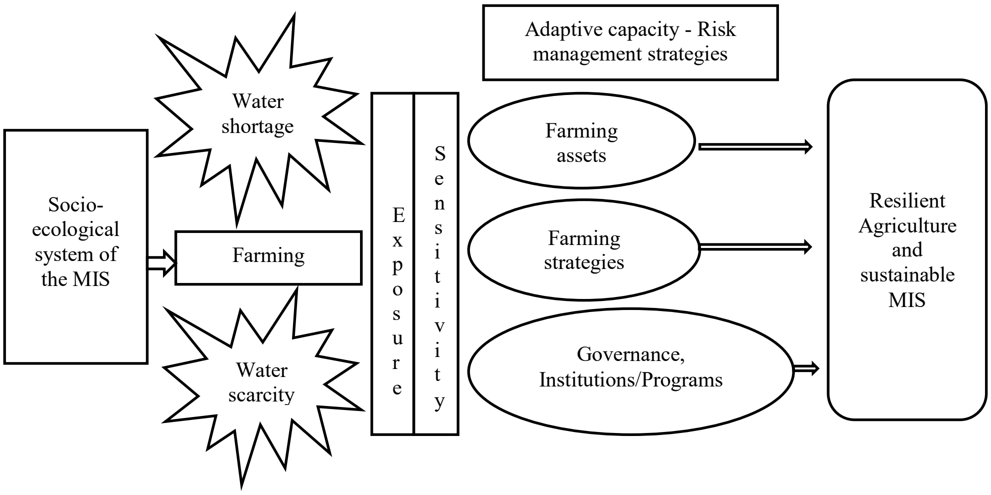

Figure 2. Framework to assess the resilience to farming in MIS

Among those identified possible risks management strategies, 20 strategies were filtered as most relevant aspects to be used as indicators to predict farmers' resilience in different irrigation systems in the study area (Table 1).

Table 1. Variables used to measure resilience

Criteria	Variables
Farming assets	1. Educational status of the farmers 2. Participation in agricultural training programmes 3. Paddy land productivity 4. Adequacy of irrigation water 5. Fair distribution of irrigation water 6. Flexibility within the field canal to change irrigation rotation 7. Minimum wastage within the irrigation rotation
Farming strategies	8. Practice water conservation cultivation measures 9. Organic fertilizer usage 10. Accessibility of agricultural input market 11. Number of information sources 12. Enrolled in livestock farming
Governance, Institutions/ Programmes	13. Farmers perception on the status of their FO 14. Effectiveness of the *Kanna* (seasonal) meeting 15. Support services provided by Department of Agrarian Development (DAD) 16. Coordination between farmers and DAD 17. Farmers' perception on the role of the president of FO *18.* Farmers' perception on the role of the *Jalapalaka* 19. Farmers' perception on the role of the Agricultural Research and Production Assistant (*KUPANISA*) 20. Farmers' perception on the role of the Divisional Officer (DO) of DAD

Data collection

Primary information was collected through structured questionnaire survey, which was carried out at 188 households belonging to eight FOs under the 16 MIS in Kumbukgate, Bamunugama and Kanagullawa *Grama Niladari* (GN) divisions in Kumbukgate, Kobeigane and Rasnayakapura ASDs, respectively. Stratified random sampling was applied based on FO level. Sample was calculated as 30 percent propotion to the number of members in each FO. But, altogether 188 households were surveyed (Table 2).

Basic information regarding tank condition on the selected village tanks (Table 3) was collected from DAD and observations were made during field visits with regard to the present situation of the selected tanks.

Data analyses

After obtaining individual information, collected information was clustered into each tank using frequency of farmer responses within each variable. Weightages were given allowing the positive side of the variable representing the highest resilience of maximum 100, and a minimum of 0 to represent the lowest resilience situation within the variable. Therefore, entire data set was converted into the percentage (0% to 100%) scale for the analysis. Table 4 represents the predicted values of variables for each tank. Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS). Clustered information or the processed values of variables were used to analyze the resilience component. For that factor analysis was performed with the principle component method and rotated (from Varimax with Kaiser Normalization technique) factor loadings were extracted to compute resilience index.

Table 2. Distribution of sample size of each FOs and tanks

FO name	FO name code	Number of member farmers	Number of surveyed farmers	Tank name	Tank name code	Number of member farmers	Number of surveyed farmers
Disanaggama Kumbukgate	DK	33	11	Ddisanakgama wewa	DW	18	6
				Kubukgate wewa	KUW	13	5
Pothana	PO	33	19	Pothana wewa	POW	33	19
Kombuwa	KO	57	35	Kombuwamaha wewa	KKW	57	19
				Kombuwakuda wewa	KMW		7
				Kombuwapansal wewa	PAW		9
Shakthi	SHA	41	12	Bogaha wewa	BOW	14	4
				Rathmalagas wewa	RW	27	8
Sriparakrama	SP	104	35	Kirimatiya wewa	KIW	87	32
				Wadu wewa	WW	3	3
Isuru	ISU	27	11	Mellagandas wewa	MW	27	11
Samagi	SA	97	48	Gala wewa	GW	31	15
				Kanagullewa wewa	KAW	15	14
				Manaweriya wewa	MAW	6	4
				Pin wewa	PIW	16	15
Vijayaba	VI	23	17	Haba wewa	HW	17	16
		415	188				

Table 3. Basic information of the selected tanks (Source: Dept. of Agrarian Development Database, 2016)

Tank no	Name of scheme	GN division	ASC division	River basin	Tank condition			Command area (Acre)	Dependent families	Floods	Droughts	Last year of rehabilitation	Weed control need	De-siltation need
					Tank bund	Sluice	Spill way							
994	DW	429	18	99	3	3		8	23	1		2013	1	1
993	KUW	429	18	99	2	4	2	10	23	1			1	1
991	POW	429	18	99	3	1	1	29	33	1		2013	1	1
995	KKW	429	18	99	3	3	1	33	54	1		2013	1	1
997	KMW	429	18	99	2	3	4	24	54	1			1	1
996	PAW	429	18	99	2	2	3	12	20	1			1	1
4970	BOW	1294	5	99	1	2	2	11	13			2014	1	1
4969	RW	1294	5	99	2	1	1	16	34			2014	1	1
4971	KIW	1294	5	99	2	2	2	63	80			2014	1	1
4972	WW	1294	5	99	2	2	2	3	3				1	1
4965	MW	1294	5	99	2	1	1	12	22				1	1
4763	GW	277	3	98	3	3	2	55	45		1	2002	2	1
4764	KAW	277	3	98	3	1	1	42	26		1	2014	2	2
4773	MAW	277	3	98	2	2	2	9	7		1		1	1
4766	PIW	277	3	98	2	3	3	24	15		1	2010	2	2
4950	HW	277	3	98	2	2	2	33	20		1	2016	2	2

GN division /429 – Kumbukgate, 1294 – Bamunugama, 277 – Kanagullawa
River basin /99 – Daduru oya, 98 – Rathambala oya
ASC division /18 – Kumbukgate, 5 – Kobeigane, 3 - Rasnayakapura
Tank condition /1- Very good, 2- Normal, 3 Week, 4 – Abandoned, 5 – Flood affected
Floods/Droughts/1 - Yes, 2 - No
Weed control/Desolation /1 - Need, 2 - Not need

Table 4. Distribution of predicted values of variables within tank level

Variables	DW	KUW	POW	KKW	KMW	PAW	BOW	RW	KIW	WW	MW	GW	KAW	MAW	PIW	HW
1	50.0	45.0	44.7	42.9	47.4	52.8	50.0	59.4	57.0	50.0	40.9	40.0	44.6	25.0	50.0	39.7
2	16.7	0.0	0.0	14.3	15.8	11.1	0.0	0.0	21.9	0.0	18.2	6.7	6.7	66.7	20.0	5.9
3	27.0	14.1	56.7	100	65.2	57.2	37.8	47.1	55.6	0.0	59.7	47.4	54.0	45.7	40.6	76.8
4	66.7	50.0	50.0	50.0	52.6	55.6	0.0	25.0	78.1	16.7	40.9	83.3	86.7	50.0	73.3	64.7
5	100	100	100	100	89.5	55.6	50.0	87.5	50.0	0.0	81.8	66.7	66.7	66.7	66.7	94.1
6	100	100	94.7	85.7	100	88.9	100	100	93.8	100	45.5	100	100	33.3	100	52.9
7	100	100	94.7	71.4	86.8	77.8	100	87.5	73.4	66.7	81.8	80.0	83.3	100	80.0	70.6
8	0.0	20.0	42.1	0.0	5.3	0.0	0.0	11.1	21.9	66.7	27.3	46.7	28.6	0.0	56.3	50.0
9	100	100	68.4	85.7	100	100.0	0.0	100	40.6	66.7	63.6	66.7	73.3	0.0	53.3	82.4
10	100	35.0	73.7	50.0	47.4	52.8	50.0	50.0	48.4	33.3	40.9	51.7	41.1	50.0	33.3	35.3
11	41.7	30.0	67.1	46.4	31.6	58.3	50.0	59.4	56.3	75.0	34.1	55.0	55.4	62.5	63.3	48.5
12	16.7	0.0	15.8	10.5	0.0	22.2	0.0	25.0	25.0	0.0	18.2	13.3	7.1	50.0	26.7	5.9
13	70.8	55.0	82.9	71.4	75.0	69.4	87.5	65.6	64.8	33.3	68.2	73.3	63.3	66.7	75.0	85.3
14	100	100	100	100	100	100.0	100	87.5	56.3	33.3	81.8	100	100	66.7	100	100
15	91.7	10.0	52.6	50.0	50.0	50.0	75.0	56.3	46.9	33.3	50.0	50.0	50.0	16.7	56.7	50.0
16	50.0	40.0	47.4	42.9	50.0	50.0	50.0	43.8	40.6	33.3	50.0	40.0	39.3	25.0	46.7	76.5
17	50.0	50.0	86.8	64.3	89.5	66.7	75.0	65.6	46.9	50.0	75.0	55.0	51.8	62.5	60.0	79.4
18	50.0	50.0	84.2	57.9	50.0	50.0	75.0	62.5	64.8	66.7	79.5	58.3	55.4	75.0	63.3	82.4
19	50.0	50.0	84.2	78.9	57.1	61.1	50.0	62.5	53.9	50.0	65.9	65.0	48.2	37.5	70.0	79.4
20	50.0	50.0	55.3	47.4	53.6	50.0	50.0	62.5	56.3	66.7	29.5	45.0	48.2	31.3	53.3	55.9

RESULTS AND DISCUSSION

Socio economic background of the study area

According to survey data, 72 percent of households are engaged in irrigated agriculture or paddy farming as their major occupation. All the sampled households, who cultivate paddy, are abstracting water from village tanks. About 68 percent of surveyed farmers had cultivated both seasons, whilst 32 percent cultivated only during *Maha* season. This information suggests that many farming communities of MIS across the region are at significant risk, if agriculture systems are stressed by events such as droughts due to water scarcity.

Among the responded farmers, the majority of them (about 93 percent) are above 49 years of age, indicating the less involvement of youth in farming activities. Only 6 percent of the total farmers represents the youths under 35 years of age. These findings reveal that a segment of the young population is either in employment seeking category or employed in outside of the agriculture sector. The statistics of the education of the respondent farmers show that the majority of them (67 percent) have received formal education from grade six to G.C.E (O/L) and 19 percent have received only primary education. Educational background of the farmers implied that the irrigated farming community in the study area has sufficient educational background to capture the irrigation system management programmes, new technological innovations and new knowledge from climate awareness programmes. Therefore, empowerment of farmers could be handled conveniently to implement necessary adaptation measures.

Paddy land distribution in the study areas showed that average lowland extent of 0.47 ha per household. The majority of farmers (71 percent) are having low land extent below 0.405 ha (1 ac). The maximum and minimum extent of low land recorded was 2.03 ha (5 ac) and 0.10 ha (0.25 ac), respectively.

Farmer's resilience to farming in MIS

The estimates obtained from the resilience analysis are reported in the flowing sections. The high correlation among variables can produce latent variables or factors considered to measure resilience. Extracted factor loadings (value >0.5 (+ or -)) to measure different factors are shown in Table 5.

Table 5. Extracted factor loadings for the observed variables used to estimate the factors related to resilience

Rotated Component Matrix[a]						
	Component					
	F1	**F2**	**F3**	**F4**	**F5**	**F6**
Education status of farmers	.842					
Participation in Agric. training	-.852					
Flexibility within field canal	.840					
Organic fertilizer usage	.559					
Livestock farming	-.659					
Perception regarding DO	.831					
Land productivity		.765				
Strength of FO		.741		.513		
Coordination with DAD		.790				
Perception regarding FO president		.741				
Perception regarding *KUPANISA*		.847				
Fair distribution of water			.658			
Number of information source			-.885			
Productivity of *Kanna* meeting			.621			
Minimum wastage within field canal				.681		
Agric. Input market				.838		
Support services from DAD				.666		
Adequacy of water to farming					.918	
Water conservation farming						.733
Perception regarding *Jalapalaka*						

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization[a]
a. Rotation converged in 16 iterations

Factor representing the contribution from the total is calculated as a fraction for resilience index as shown in Table 6.

The value of the selected factor loadings was multiplied by predicted values of variables from different tanks and summation of relevant variables were taken as the values of extracted factors (Table 7).

Table 6. Fraction of the factors in resilience index

Factor	% Variance	Fraction
F1	21.470	0.254765
F2	20.255	0.240343
F3	14.034	0.166522
F4	12.593	0.149428
F5	9.392	0.111449
F6	6.531	0.077499
Total	84.275	1

Accordingly, the empirical equation to calculate resilience index was given as;

$$R = 0.25*F1 + 0.24*F2 + 0.17F3 + 0.15F4 + 0.11F5 + 0.08F6$$

Resilience index is divided into three categories as high (>0.75), moderate (0.50 – 0.75) and low (<0.50). The total resilience index value of 0.555 represents moderate resilience situations within the MIS in IL_3 agro-ecological region in the Kurunegala district. This shows that there is adequate space to enhance the resilience of farming by introducing and adapting various risk management strategies in this region. According to the results, Pothana *wewa* (0.637) was found to be the most resilient among the tested tanks, followed by Dissanaggama *wewa* (0.614) and Haba *wewa* (0.600). Whilst most of the tanks showed a resilience index around 0.5, only two tanks, namely, Waduwage *wewa* (0.432) and Manaweriaya *wewa* (0.466) scored a resilience index of less than 0.5.

Although there is no significant relationship between the capacity of the tank and the resilience situation, tanks with lower capacity and command area tends to be less resilient than larger tanks. The smallest tanks among the sample such as Wadu *wewa,* Manaweriya *wewa* and Kumbukgate *wewa* are the least resilient tanks, which feed below 10 ac of command area. However, Dissanaggama *wewa*, which provides water to 8 ac command area showed comparatively high resilience. The reasons for such high resilience were due to the accessibility of services and the trust of the farmers both on their FO and the agency officials.

Table 7. Extracted factors related to resilience and computed resilience index

FO Names	Tanks Names	F1	F2	F3	F4	F5	F6	Resilience (R)	Resilience index (tanks)	Resilience index (FOs)	Resilience index (ASD)
DK	DW	248.733	215.911	164.775	239.876	61.200	0.000	184.727	0.614	0.559	0.587
	KUW	219.340	190.005	154.450	124.997	45.900	14.660	151.664	0.504		
PO	POW	211.824	293.427	187.288	192.827	45.900	30.863	191.660	0.637	0.637	
KO	KKW	214.471	281.156	168.989	150.995	45.900	0.000	177.522	0.590	0.590	
	KMW	237.755	272.811	148.921	160.644	48.316	3.858	179.950	0.598		
	PAW	240.667	251.254	150.281	156.893	51.000	0.000	175.159	0.582		
SHA	BOW	167.650	251.988	139.250	193.212	0.000	0.000	155.044	0.515	0.553	0.517
	RW	258.306	238.995	164.459	163.896	22.950	8.144	177.654	0.590		
SP	KIW	231.336	218.905	117.613	146.470	71.719	16.034	161.508	0.537	0.484	
	WW	218.767	161.875	87.075	108.204	15.300	48.867	130.167	0.432		
ISU	MW	160.225	261.781	134.816	149.218	37.555	19.991	153.915	0.511	0.511	
SA	GW	206.808	236.142	154.642	158.953	76.500	34.207	169.660	0.564	0.542	0.553
	KAW	213.036	214.781	154.958	148.543	79.560	20.943	163.858	0.544		
	MAW	164.769	200.775	140.579	146.442	45.900	0.000	140.292	0.466		
	PIW	234.847	247.294	162.017	148.663	67.320	41.231	178.608	0.593		
VI	HW	179.265	318.341	166.978	143.370	59.400	36.650	180.576	0.600	0.600	
	Total sample	212.987	240.965	149.818	158.325	48.401	17.216	166.998	0.555	0.555	0.555
	Ideal situation	458.300	388.400	216.400	269.800	91.800	73.300	301.011	1.000	1.000	1.000

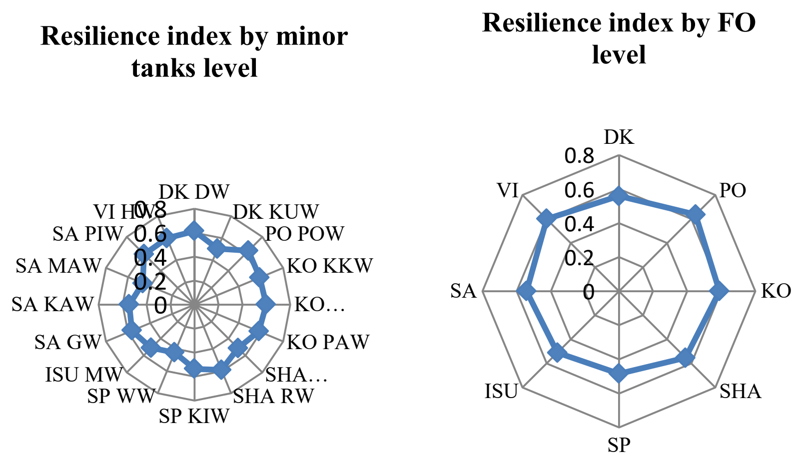

Figure 3. Resilience index by minor tanks and FOs level

It was also found that least resilient tanks have not been rehabilitated recently, though the sluice, spillway and tank bund appear to be in working condition. Aquatic plants control such as Salvinia, Water Hyacinth and de-siltation are the critical problems, which need to be addressed without further delay.

There is strong relationship between the land productivity and the resilience index. The tanks with low resilient index, such as Wadu *wewa* and Kumbukgate *wewa* has a land productivity of 2.1 t/ha and 2.6 t/ha respectively. The maximum productivity of 5.4 t/ha was recorded in Kombuwa kuda *wewa* with a resilience index of 0.59. The land productivity of most resilient tank within the sample, namely, Pothana *wewa* with 4 t/ha was found to be above the average value of 3.7 t/ha. It was observed that less resilient tanks did not have adequate water to cultivate both seasons. In contrast, comparatively high resilient tanks like Pothana *wewa,* Haba *wewa* etc. have adequate water to cultivate both seasons. Therefore, it is necessary to introduce water saving measures/technologies to enhance the resilience of such farmers in MIS.

Governance and institutional arrangements also have a major role in implementation of works related to farming to enhance the resilience of farmers. Personal relations of the officials and farmers and the trust on FOs have made a considerable difference in the resilience situation of tanks. The result shows that, comparatively high resilient tanks represent the higher value of trust (eg: Pothana *wewa,* Haba *wewa* etc.) of their FOs activities. Farmers trust on Pothana *wewa* FO activities and the services provided by the officials is characterized by higher values, while Sri Parakrama FO represents the least resilience. The farmers of Sri Parakrama FO made negative comments on their FO activities and the supports provided by the officials during the field visits.

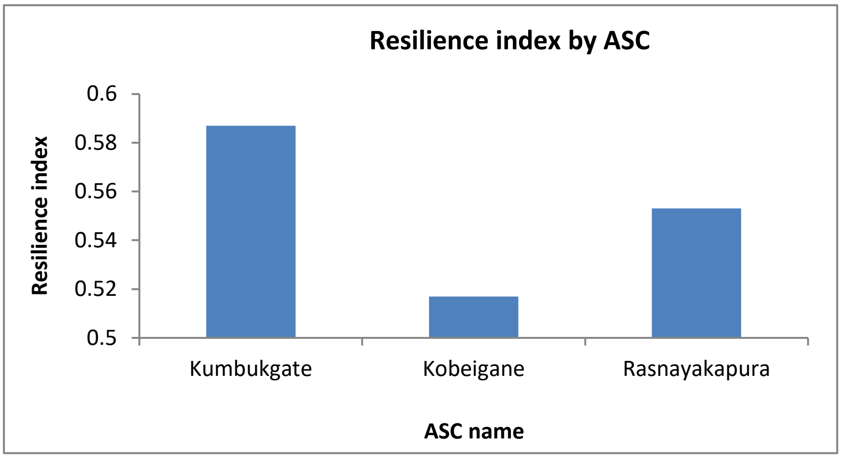

Figure 4. Resilience component by ASDs level

Figure 4 shows the average resilience index of tanks belongs to three ASDs. The differences of resilience index are mainly due to the accessibility to market facilities. It is high in Kumbukgate ASD followed by Rasnayakapura and Kobeigane.

CONCLUSIONS

Using the empirical equation derived from the study, the resilience of MIS was quantitatively determined. The results showed that resilient component of each MIS as well as FO is fluctuating around the mid value (0.5), implying that there is adequate space to enhance the resilience of farming in MIS by introducing and adapting various risk management strategies. It appears that farming assets, farming strategies and institutional interventions are important to enhance resilience. In addition, capacity of the tank, accessibility of support services and the trust of farmers on FOs and the agency officials are some of the key factors, which determine the resilience of farming in MIS. Therefore, to enhance the resilience, it is recommended to augment tank storage by removing aquatic weeds and de-silting, introduce water saving measures/technologies, strengthen the FOs, improve governance of MIS and develop access to market facilities.

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