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Vulnerability of Smallholder Farmers to Climate Change: A Case Study from Hakwatuna-Oya Irrigation Scheme in Sri Lanka

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ABSTRACT: *A system is said to be vulnerable when it is unable to cope with the adverse effects of climate change, including climate variability. Vulnerability is widely used in development and adaptation contexts. Policies, institutions and other types of interventions and initiatives from the government have a notable influence on the vulnerability of the population. Hakwatuna-oya major irrigation scheme in Sri Lanka was selected for the study to identify the socio-economic and socio-demographic factors affecting the vulnerability of smallholder farmers to climate change or variability. Primary and secondary data were collected in all the 17 GN divisions. A composite index of vulnerability was developed and mapped the vulnerability according to the index. Out of the 17 GN divisions, 6 GN divisions, namelyBogolla, Indigolla, Siyambalawewa, Elagamuwa, Rambe and Thambuwawere moderate to highly venerable. Vulnerable GN divisions account for 38 % of the land area and 41% of the population. Vulnerability is influenced by many socio-economic factors in the area.*

Keywords: *Climate change, Hakwatuna-oya,smallholder farmer, vulnerability, vulnerability index*

INTRODUCTION

Vulnerability is defined by IPCC as "the degree to which a system is susceptible to, or unable to cope with the adverse effects of climate change, including climate variability and extremes". It is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC, 2001; IPCC, 2007). Therefore, the vulnerability of a system depends on internal characteristics (sensitivity and adaptive capacity) of the population and the external factors as climate hazards.

Vulnerability is widely used in development and adaptation contexts. Policies, institutions and other types of interventions and initiatives from the government have a notable influence in internal characteristics of the population. Therefore, key vulnerabilities identified by vulnerability assessment can guide policy makers and implementer to identify the geographic areas and groups of people that have to prioritized and focused. Further, vulnerability assessment facilitates to identify the factors contributing to increase the vulnerability. This helps for better policy decisions and implementations to focus on the real need of the specific group. Therefore, this study was formulated to identify the socio-

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economic and socio-demographic factors affecting the vulnerability of smallholder farmers to climate change or variabilityatGramaNiladhari (GN) division level.

METHODOLOGY

According to FAO, “smallholder farmer” is defined as; “Farmers those who depend on small-scale subsistence farming as their primary source of income. The average size of operational holdings (actual area cultivated) is only 0.8 hectares (2 acres) or less” (Thapa, 2009).

Selection of sample

Hakwatuna-oya major irrigation scheme was selected for the study. The scheme is situated within the Daduruoya river basin and within the Divisional Secretariat of Polpithigama in the Kurunegala district. It has 3020 farm families distributed over 17 GramaNiladhari (GN) administrative divisions (Figure 1).

Data collection

Primary and secondary data were collected in all the 17 GN divisions using semi-structured questionnaire, key informant interviews and field observations. Secondary data were collected through government officials who are working in the area. Semi-structured questionnaire was developed to gather data on five themes, namely socioeconomic characteristics of farmers, cultivation information, perception to the climate variability, adaptation measures for climate variability and government policy interventions. Questionnaire survey was conducted in every GN division. The population was stratified based on GN divisions and stratified random sampling technique was used to identify the number of households to be surveyed in each GN division. Table 1 shows the distribution of sample units in each GN division. Only the households who are cultivating paddy as a primary or secondary income source were interviewed. Individuals for interviewing were selected randomly within the GN division. Altogether, 298 households were interviewed. Collected data were first filtered based on the land area cultivated (holdings that are less than 2 ac.) and main income source (agricultural) to identify smallholder farmers.

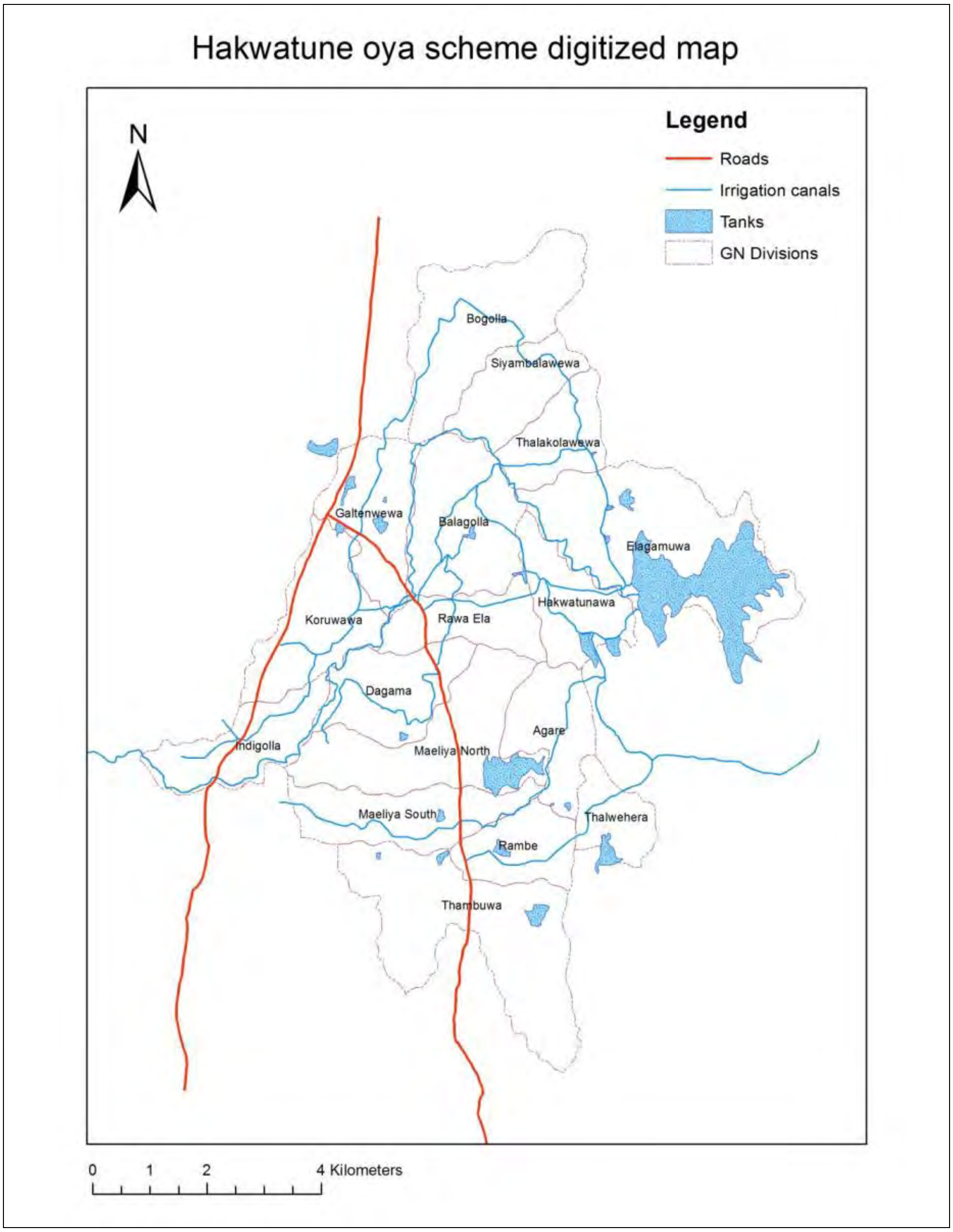


Fig. 1. Map of theHakwatuna-oyairrigation scheme

Table 1. Sample size at GN division level for household survey

	GN division	GN Code	Land area (ha)	No. of farm families	Sample size
1	Agare	373	185	113	11
2	Balagolla	368	612	254	25
3	Bogolla	352	399	350	35
4	Dagama	370	313	145	14
5	Elagamuwa	398	332	191	19
6	Galtanwawa	366	291	308	31
7	Hakwatunawa	395	220	195	19
8	Indigolla	367	502	244	24
9	Koruwawa	365	345	220	22
10	MaeliyaDakuna	372	352	216	21
11	MaeliyaUthura	371	252	135	13
12	Rambe	374	85	83	8
13	Rawaela	369	122	60	6
14	Siyambalawewa	396	133	234	23
15	Thalkolawawa	397	130	81	8
16	Thalwahara	392	51	30	3
17	Thambuwa	387	169	160	16
	Total			**3019**	**298**

Vulnerability assessment

Index based approach for vulnerability assessment was used in the study. A composite index of vulnerability was developed. The framework developed by IPCC was used as the base for assessing the vulnerability (IPCC, 2007). According to this framework, vulnerability is a function of exposure, sensitivity and adaptive capacity.

Vulnerability = f (exposure, sensitivity, adaptive capacity)

where;

Exposure - The nature and degree to which a system is exposed to significant climatic variations.

Sensitivity - The degree to which a system is affected, either adversely or beneficially, by climate related stimuli.

Adaptive capacity - Potential or ability of a system, region, or community to adjust to the impacts of climate change.

Exposure and sensitivity affect vulnerability positively and adaptive capacity affects negatively. Only sensitivity and adaptive capacity were considered as the components in calculating the vulnerability index. Exposure was not included in this study for calculating the vulnerability index, as it is difficult to collect rainfall and temperature data separately for each and every GN divisions in the Hakwatuna-oya scheme due to unavailability of rainfall data in each GN division. Further, considerable difference in rainfall among each GN division cannot be expected as the geographic area under consideration is small.

Proxy variables for each component of sensitivity and adaptive capacity were identified and the relationship between proxy variables and vulnerability was established (Table 2)based on available literature (Eriyagama, 2010; MoE, 2011; Punyawardena, 2013). Five proxy variables were used to calculate sensitivity component index and nine proxy variables were used to calculate adaptive capacity component index.

All the proxy variables of sensitivity were categorized into two sub-indicators as human sensitivity and livelihood sensitivity. Similarly, all the adaptive capacity proxy variables were categorized into two sub-indicators as socio-economic adaptive capacity and infrastructure adaptive capacity (Figure2).

Variables were calculated with secondary and primary data as shown in Table 2 Considering the relationship of the variable to the final vulnerability, normalization was done using Equations 1 and 2. If the relationship is positive, Equation 1 was used and if the relationship is negative, Equation 2 was used.

$$X = \frac{Xac - Xmin}{Xmax - Xmin} X100 \ldots\ldots\ldots\ldots\ldots \textbf{(Eq. 1)}$$

$$X = \frac{Xmax - Xac}{Xmax - Xmin} X100 \ldots\ldots\ldots\ldots\ldots \textbf{(Eq. 2)}$$

Where;

X = normalised value of the variable

Xac = actual value of the variable

Xmin = minimum value of the variable of the dataset

Xmax = maximum value of the variable of the dataset

Table 2. Variables used in vulnerability assessment

Indicators	Variables	Relationship to vulnerability	Method of calculation	Source of data
Human Sensitivity	Population density	+ve	Population/Area	Secondary
	Agriculture based households	+ve	Agriculture based HH/Population	Secondary
	Agriculture labour force	+ve	Agriculture labour force/Total labour force	Secondary
Livelihood Sensitivity	Area cultivated by agro-wells	-ve	Area cultivated by agro-wells/ Area GN division	Secondary
	Small-scale farming	+ve	No of HH cultivating under 2 acre paddy land/ Total no of HH	Questionnaire
Socio-economic Adaptive Capacity	People educated up to grade 5 or above	-ve	No of HH educated up to grade 5 or above/Total no of HH	Questionnaire
	HH heads suffering from chronic diseases	+ve	No of HH heads with chronic diseases/ Total No of HH	Questionnaire
	Unemployment	+ve	People unemployed/ Population of GN	Secondary
	HH with salaried employments	-ve	No of HH with salaried employments/ Population of GN	Secondary
	Dependency ratio	+ve	People at dependant age/ Population of GN	Secondary
	Poverty head count index	+ve	No of people under poverty line/Population of GN	Secondary
	Landless farmers	+ve	No of HH who do not own paddy lands/ Total no of HH	Questionnaire
Infrastructure Adaptive Capacity	Surfaced road density	-ve	Length of surfaced road/ Area of the GN	Secondary
	HH with assured drinking water	-ve	HH with own well and piped water line/Total No of HH	Secondary

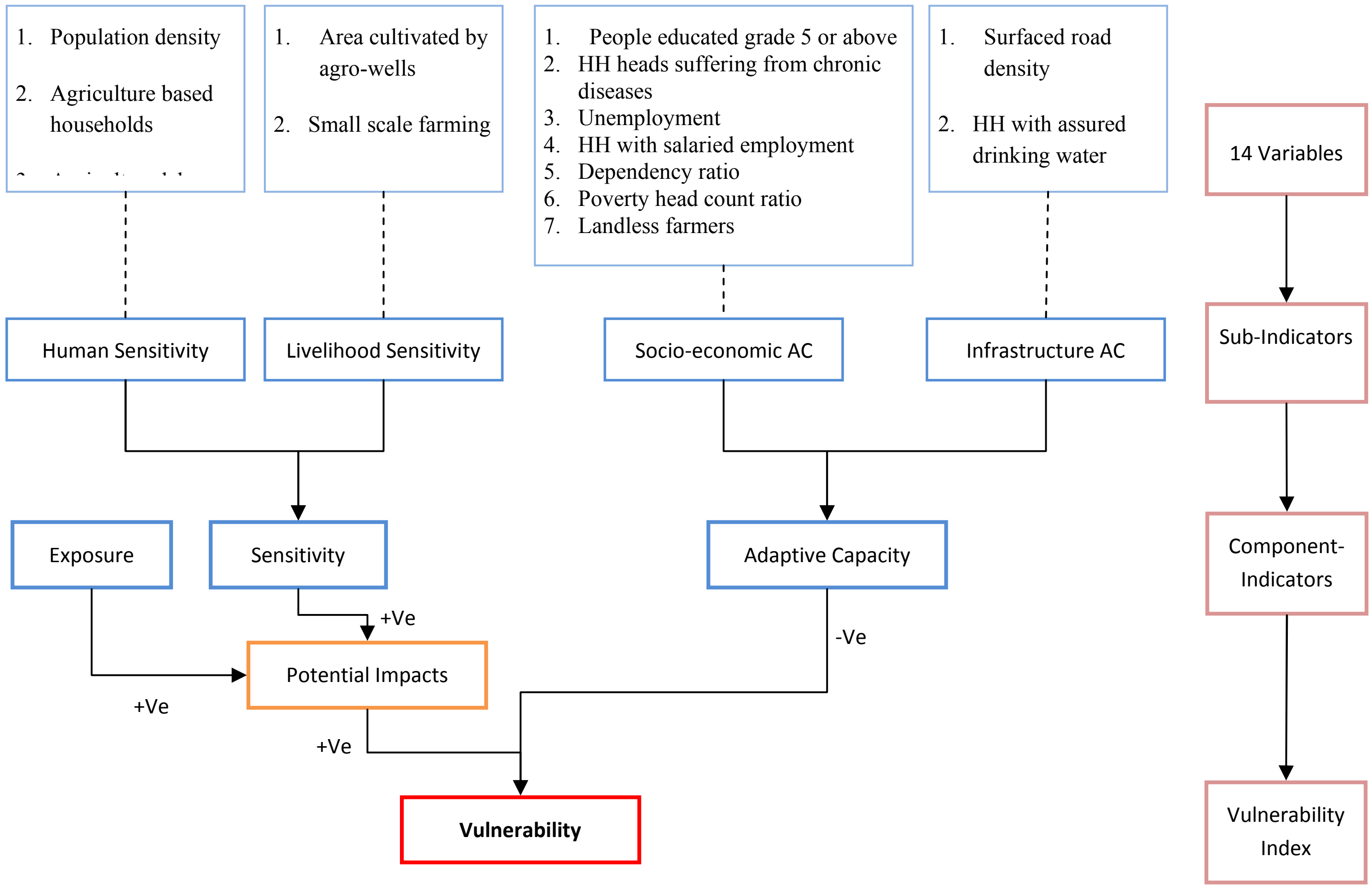


Fig.2. **Framework for vulnerability assessment**

The normalized variables within each sub-indicator were averaged to form each component indicators of the vulnerability index. Then the component indicators were averaged to form the vulnerability index. In averaging, equal weightage was given to all the indicators used.

Each sub-indicator, component indicators and vulnerability index was mapped atGN division level using ArcGIS software. Five severity levels of vulnerability was used to show the final vulnerability levels of each GN division as highly vulnerable, vulnerable, moderately vulnerable, low vulnerable and very low vulnerable. Equal interval technique in ArcGIS software was used to categorize the vulnerability index into the above five severity levels.

RESULTS AND DISCUSSIONS

Vulnerability of smallholder farmers to climate change

Figure3 indicates that Indigolla, Maeliya North, Siyambalawewa and ThalwaharaGN divisions are highly vulnerable in terms of human sensitivity. According to Table 3, high population density and high percentage of agriculture based households are the reasons for high vulnerability in terms of human sensitivity. BogollaGN division is highly vulnerable in terms of livelihood vulnerability. According to the Table 4, less area cultivated by agro-wells and high percentage of small-scale farming are the reasons for high livelihood vulnerability. According to the sensitivity index in Figure 3, Bogolla and Indigolla are very-highly sensitive GN divisions to climate change in the Hakwatuna-oya scheme.

Table 3. Human sensitivity to climate change vulnerability

GN division	Normalized variables*				
	Population density	Agriculture based households	Agriculture labour force	Index value	Rank
Agare	33	36	18	29	10
Balagolla	14	22	10	15	15
Bogolla	0	65	25	30	9
Dagama	26	10	4	13	16
Elagamuwa	3	32	15	17	14
Galtanwawa	42	10	9	21	12
Hakwatunawa	28	21	10	19	13
Indigolla	14	100	42	52	2
Koruwawa	33	67	29	43	5
Maeliya North	56	54	37	49	4
Maeliya South	36	0	0	12	17
Rambe	100	18	8	42	6
Rawaela	42	20	10	24	11

Siyambalawewa	29	92	42	54	1
Thalkolawawa	42	36	17	32	8
Thalwahara	67	60	25	51	3
Thambuwa	19	57	26	34	7

*If the value of normalized variable is high, its' contribution to vulnerability is also high.

Table 4. Livelihood sensitivity to climate change vulnerability

GN division	Normalized Variables*			
	Area not cultivated by agro-wells	Small-scale farming	Index value	Rank
Agare	75	19	47	13
Balagolla	100	44	72	3
Bogolla	94	100	97	1
Dagama	72	25	48	12
Elagamuwa	100	26	63	5
Galtanwawa	79	31	55	7
Hakwatunawa	100	30	65	4
Indigolla	100	58	79	2
Koruwawa	100	3	52	10
Maeliya North	0	21	10	17
Maeliya South	67	9	38	14
Rambe	63	0	31	15
Rawaela	97	2	49	11
Siyambalawewa	69	46	58	6
Thalkolawawa	100	7	54	8
Thalwahara	59	2	31	16
Thambuwa	93	14	53	9

*If the value of normalized variable is high, its' contribution to vulnerability is also high.

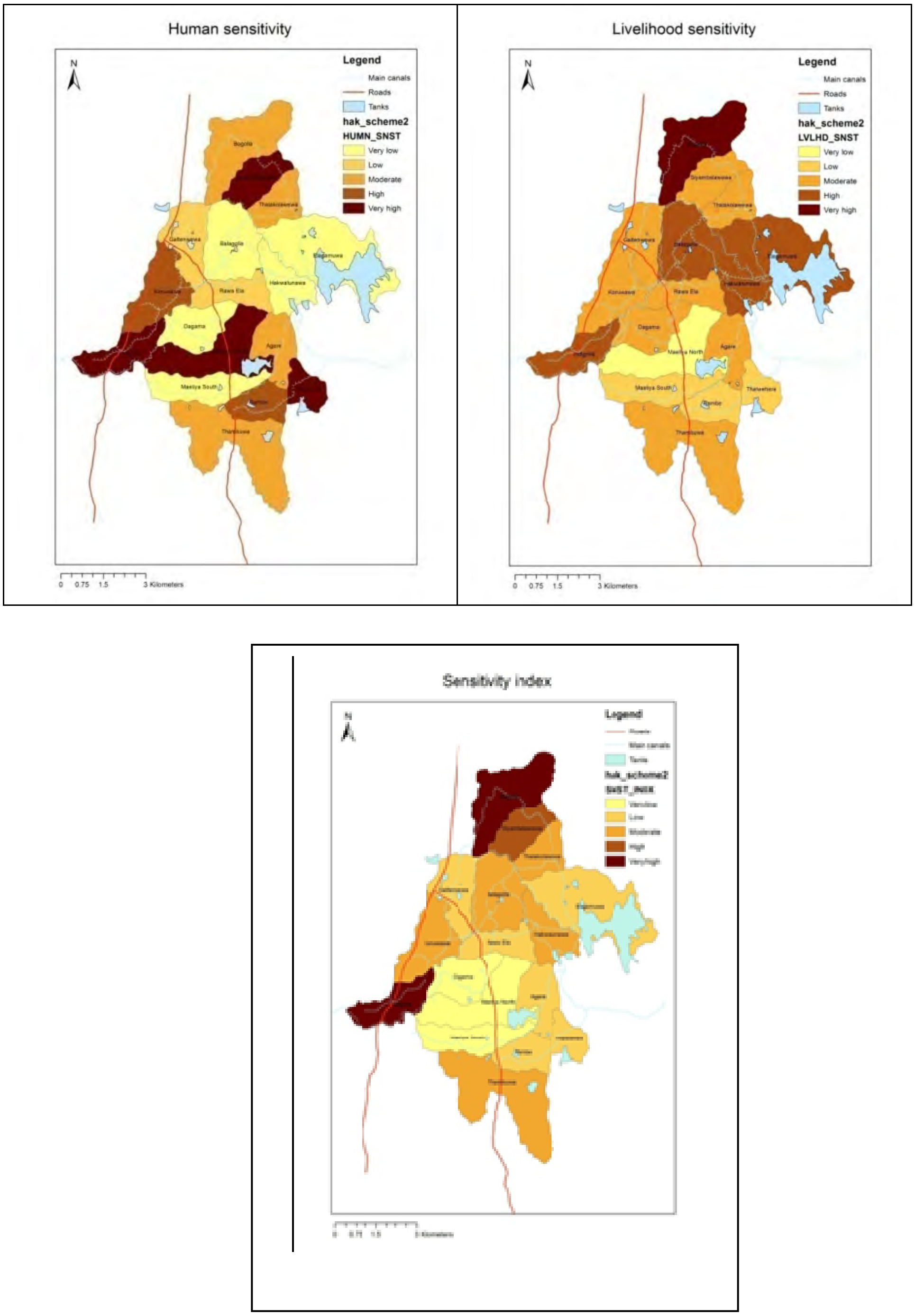
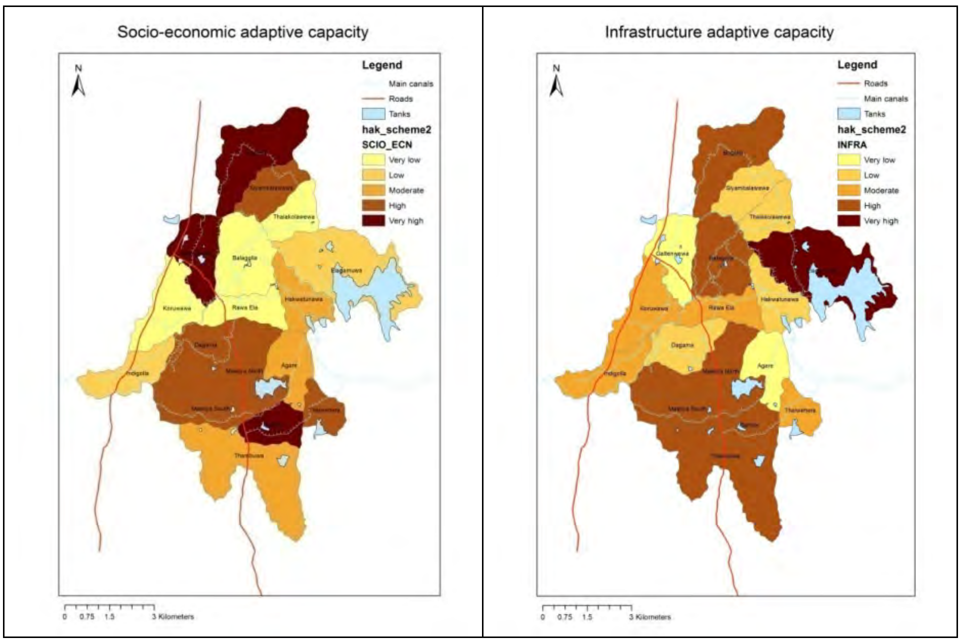


Fig.3. Sensitivity to climate change vulnerability

According to Figure 4, Bogolla, Galtanwewa and RambeGN divisions are highly vulnerable in terms of socio-economic adaptive capacity. It means, they have least adaptive capacity to climate variability. Rambe and Bogolla have very less percentage of farmers whose income is contributed with government or private salaried employments (Table 5). This leads them to depend more on agricultural sources as the household income. This is one reason for them to become more vulnerable in terms of socio-economic adaptive capacity. Further, Rambe has high percentage of household heads with less educational level (below grade 5) and high percentage of unemployment level, which further reduced the adaptive capacity (Table 5). BogollaGN division has high percentage of households suffering from chronic diseases and high level of poverty head count ratio. These factors have reduced the adaptive capacity of these GN divisions. Therefore, the absence of alternative livelihood opportunities, low educational levels, presence of chronic diseases, unemployment, high dependency ratio and prevalence of high levels of poverty are the reasons for reduced adaptive capacity.

ElagamuwaGN division is highly vulnerable to climate change in terms of infrastructure adaptive capacity. The reason is that this area lack in properly developed road system and has very less percentage of households with assured drinking water (Table 6). These two factors have decreased the adaptive capacity of this area and increased the vulnerability to climate change.



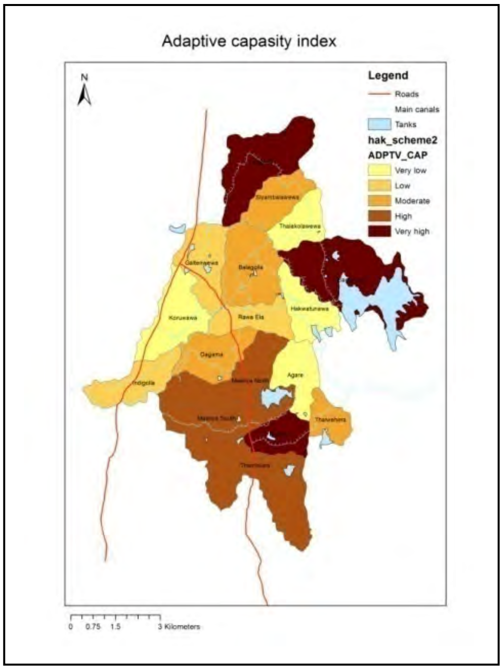


Fig.4. Adaptive capacity to climate change vulnerability

Table 5. Socio-economic adaptive capacity to climate change vulnerability

	Normalized Variables*								
GN division	**HHnot educated up to grade 5 or above**	**HH heads suffering from chronic diseases**	**Unemployment**	**HH without salaried employments**	**Dependency ratio**	**Poverty head count index**	**Landless farmers**	**Index**	**Rank**
Agare	11	69	68	71	45	21	45	47	10
Balagolla	47	45	0	16	35	61	7	30	16
Bogolla	57	100	56	85	0	100	69	67	1
Dagama	18	81	93	72	41	29	71	58	4
Elagamuwa	17	60	52	100	41	5	18	42	12
Galtanwawa	62	76	52	88	100	13	39	61	3
Hakwatunawa	17	80	80	0	36	54	53	46	11
Indigolla	75	47	51	28	17	37	0	36	13
Koruwawa	20	52	15	60	23	11	30	30	15
Maeliya North	42	36	75	87	83	23	56	57	5

Maeliya South	67	87	36	74	65	13	26	53	8
Rambe	100	47	81	94	27	8	83	63	2
Rawaela	8	0	73	65	41	19	28	33	14
Siyambalawewa	45	49	96	74	32	55	36	55	7
Thalkolawawa	0	47	62	54	33	0	0	28	17
Thalwahara	15	76	100	68	19	15	100	56	6
Thambuwa	75	24	78	91	32	9	31	48	9

*If the value of normalized variable is high, its' contribution to vulnerability is also high.

Table 6. Infrastructure adaptive capacity to climate change vulnerability

GN division	Normalized variables*			
	Un-surfaced road density	**HH without assured drinking water**	**Index**	**Rank**
Agare	58	0	29	17
Bogolla	89	70	79	6
Balagolla	100	61	80	9
Dagama	78	31	55	15
Elagamuwa	94	100	97	1
Galtanwawa	0	70	35	5
Hakwatunawa	68	23	45	16
Indigolla	76	46	61	13
Koruwawa	88	33	61	14
Maeliya North	77	72	75	4
Maeliya South	89	64	77	8
Rambe	61	92	77	2
Rawaela	73	59	66	10
Siyambalawewa	53	52	52	12
Thalkolawawa	53	53	53	11
Thalwahara	34	90	62	3
Thambuwa	91	64	78	7

*If the value of normalized variable is high, its' contribution to vulnerability is also high.

Sensitivity and adaptive capacity component indicators were combined and overall vulnerability of each GN divisions to climate change was assessed. According to the Figure 5, BogollaGN division is very highly vulnerable to climate change and IndigollaGN division is highly vulnerable to climate change. The reason is Bogolla is very highly vulnerable in both sensitivity and adaptive capacity while Indigolla is highly vulnerable only in adaptive capacity. Siyambalawewa, Elagamuwa, Rambe and Thambuwa are moderately vulnerable to climate change. Galtenwewa, Thalakolawewa, Hakwatunawa, Rawaela, Dagama and AgareGN divisions are least vulnerable to climate change.

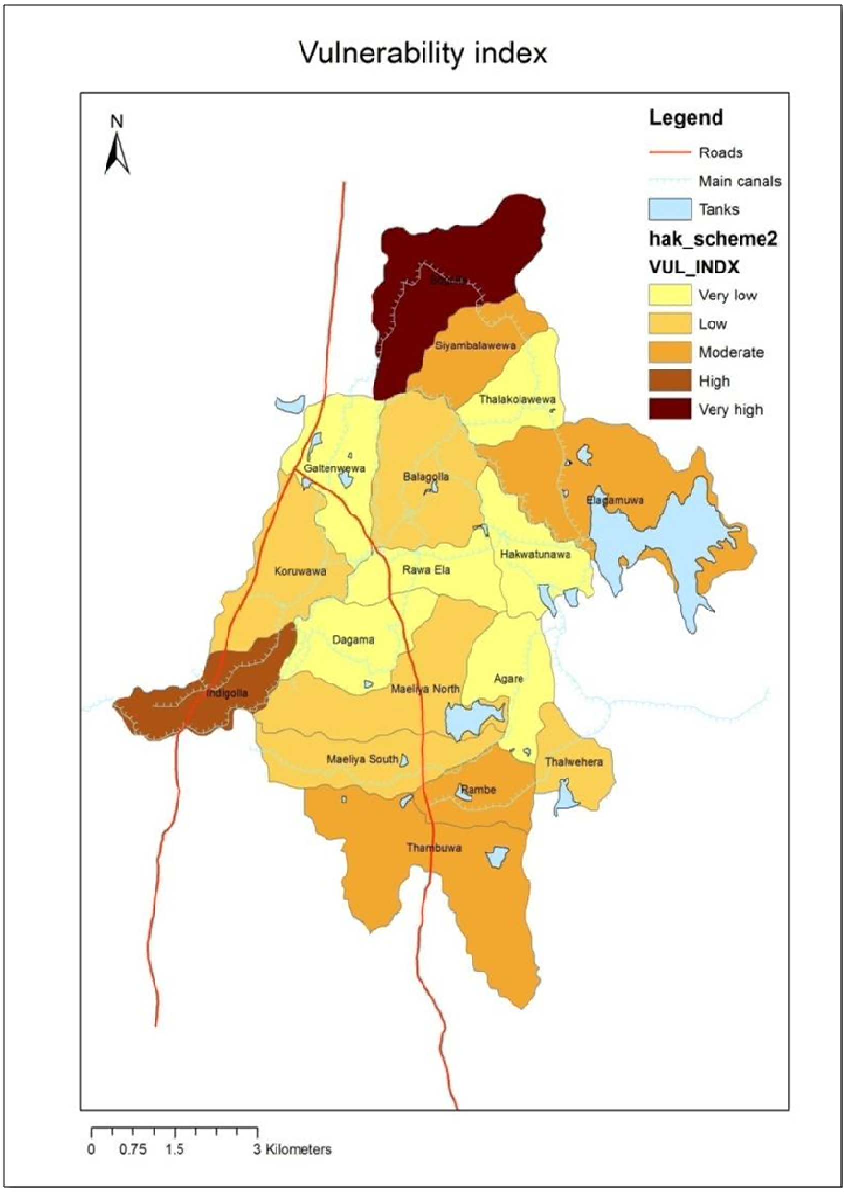


Fig. 5. **Overall vulnerability of the study area to climate change**

CONCLUSIONS

Sensitivity to climate change is influenced by population density, agriculture based households, area cultivated by groundwater sources and percentage of small scale farming.

Adaptive capacity in the study area to climate change is affected by education, chronic diseases, having government of private employments, dependency, poverty, road density and assured drinking water source to farmers.

Out of 17 GN divisions, 6 GN divisions are moderate to highly venerable. They are Bogolla, Indigolla, Siyambalawewa, Elagamuwa, Rambe and ThambuwaGN divisions. Vulnerable GN divisions account for 38 % of the land area and 41% of the population. It is suggested to consider this information in selecting GN divisions for climate change adaptation interventions.

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