TA 7189-INO INSTITUTIONAL STRENGTHENING FOR INTEGRATED WATER RESOURCES MANAGEMENT IN THE 6 CIS RIVER BASIN TERRITORY (PACKAGE E)

VULNERABILITY AND CLIMATE RISK ASSESSMENT OF VILLAGES AT THE CITARUM RIVER BASIN

Integrated Climate Change Mitigation and Adaptation Strategy for the Citarum River Basin (Package E)

CCROM-SEAP, Bogor Agricultural University

AECOM

Asian Development Bank

Ministry of Environment, Republic of Indonesia

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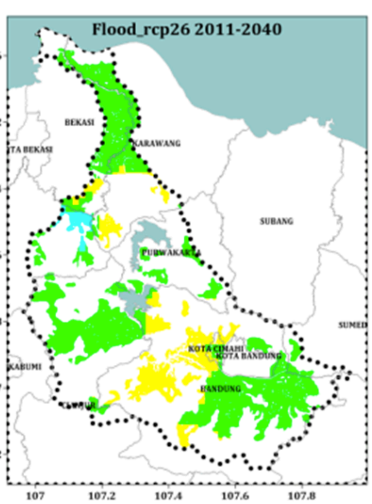

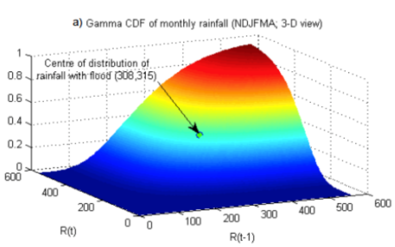

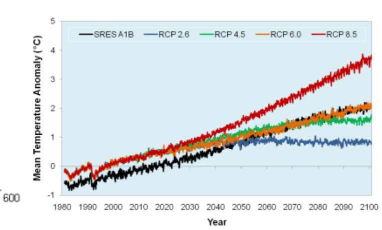

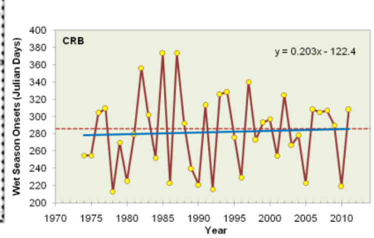

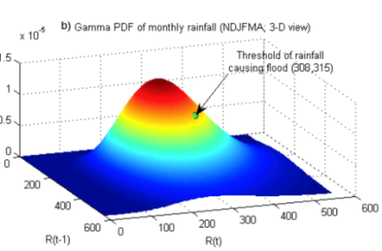

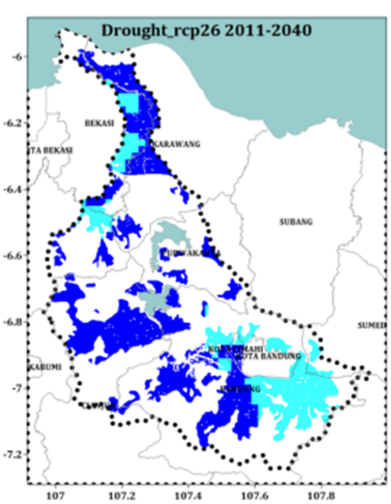

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VULNERABILITY AND CLIMATE RISK ASSESSMENT OF VILLAGES AT THE CITARUM RIVER BASIN

Integrated Climate Change Mitigation and Adaptation Strategy for the Citarum River Basin (Package E)

Prepared By:

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2013 || CCROM-SEAP, Bogor Agricultural University | AECOM | Asian Development Bank (ADB) | Agency for Envionmental Management of West Java Province | Ministry of Environment, Republic of Indonesia

1 INTRODUCTION

1.1 Background

Citarum River Basin (CRB) is one of Indonesia's most strategic basins in Indonesia where millions of people rely on the basin to support their economic activities and livelihood. However, the basin is facing various problems such as pollution, sanitation, and environmental problems like deforestation, drought, siltation, and flooding. A number of studies suggested that deforestation will continue to the future (WWF, 2007, Ardiansyah et al., 2013). The forest degradation, being turned into farm-yards, or farm-yards into empty land, or farm-yards turned into housing areas will become more visible. Changes from natural land use (forests, farm-yards, empty lands) into housing area or even industrial area as well as development of transportation infrastructure (roads, terminal, etc.) will also increase. This situation will bring the CRB into more serious problems.

The shift from vegetation into non-vegetation area is causing water catchments volume deficit, thus depleting the water supply. Besides, the direct run off increases as infiltration decreases, followed by increased surplus of water on the surface. Thus the problem of flood during wet season and drought during dry season will become more intense. With climate change, this condition will get worse (Boer et al., 2012). Recent study suggested that under land use of 2000, the return period of having heavy flood was only once in 14 years, under land use of 2010 and 2025, it increased to once in 13 and 10 years respectively. Climate change would increase the frequency of flood risk even more. Under land use of 2010, the return period of flood risk will increase from once in 13 years to once in 5 years (Rakhman, 2013).

Taken the above concerns, it is very important to promote climate-resilient development in the Citarum River Basin (CRB) and create an environment conducive to mainstreaming climate change concerns into CRB water resource planning to reduce the vulnerability of the local communities and improve their livelihoods. The availability of vulnerability and climate risk assessment at the CRB will be very useful for assisting the community and other stakeholders to better design strategy, programs and actions to reduce the impact of climate change and improve the condition of the CRB into climate resilient basin.

1.2 Objectives

The objectives of the study are:

1. To analyze the vulnerability of villages in CRB to potential impact of climate changes,
2. To assess the level of climate risk of the villages in CRB, and
3. To identify priority locations for adaptation based on the results of vulnerability and climate risks assessments

2 VULNERABILITY AND CLIMATE RISK ASSESSMENT

2.1 Vulnerability Concept

Vulnerability assessment is one of the critical steps in developing climate change resilience planning. This assessment helps to ensure that resilience strategies and interventions will target the most vulnerable populations, and address the greatest risks to sectors and systems. The result of the vulnerability assessment could inform what existing capacities to adapt, what the potential differential impacts of climate change, who and what the most vulnerable groups/sectors/systems, what factors that make the groups/sectors/systems vulnerable and how they may be affected, and what adaptation strategies and interventions that enhance their resilience.

The resilience of the system to the impact of climate change will depend on its vulnerability level. The more vulnerable the system, the less resilient the system is to the climate change impact. Among the literature, the definition of vulnerability varies. The more commonly used and widely accepted definition of vulnerability in the context of climate change assessments is the one proposed by the Intergovernmental Panel on Climate Change (IPCC) in its assessments reports. IPCC (2001, 2007) defines ***vulnerability*** as '*The degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity'*. Thus the vulnerability is measured using three dimensions, namely level of exposure, level of sensitivity and adaptive capacity.

Exposure is the degree, duration and/or extent in which the system is in contact with, or subject to, the perturbation (Adger 2006 and Kasperson et al. 2005 in Gallopin 2006). Sensitivity is internal to the system and is determined by the human and environment conditions. The human conditions constitute the social and human capital and endowments such as population, entitlements, institutions, economic structures and so on. The environmental conditions comprise the natural or biophysical endowments, such as soils, water, climate, mimeral, and ecosystems structures and functions. Both the human and environmental conditions influence the adaptative capacity of the system exposed to climate variations which also shapes the nature and degree of climate change impacts. Adaptive capacity is defined as as the "ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (IPCC 2007).

Jones et al. (2004) combine the concept of vulnerability with coping range. The system is said to be vulnerable to climate change when the system is being exposed to a particular climate event that beyond the capacity of the system to cope with it (called beyond the coping range), so that the system will be negatively impacted by the event (get loss). The level at which the risk of an impact becomes 'dangerous' is called as critical threshold (cf. Parry 1996). Therefore, if level of the vulnerability remains the same to the future (no change in coping range), the system will be exposed to more frequent and higher loses if the climate changes. With adaptation, the vulnerability of the system will reduce or the coping range will increase. Adaptation in this case can be related to actions or measures that may reduce the level of exposure or level of sensitivity of the system, and conditions that enable the system to improve the adaptive capacity. Simple schematic showing relationship between coping range, vulnerability, and adaptation is shown in Figure 2-1.

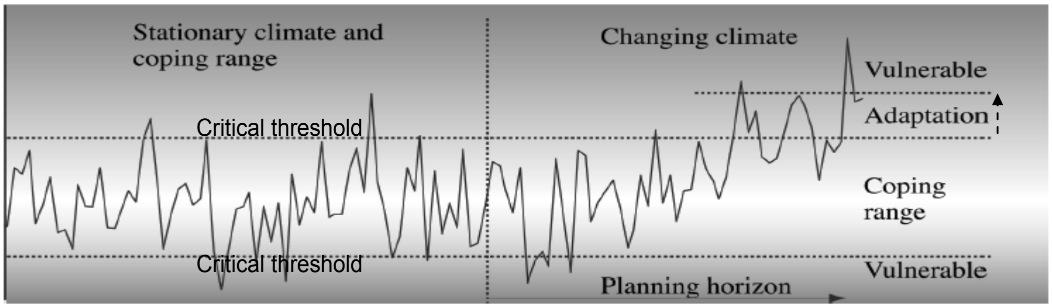


Figure 2-1 Relationships of Coping Range, Vulnerability, and Adaptation, The critical thresholds separate the coping range from a state of vulnerability (adapted from Jones et al., 2004).

2.2 Factors Shaping Vulnerability Level

As describe above, vulnerability is measured using three factors, namely level of exposure, level of sensitivity and adaptive capacity. Biophysical, social and economic indicators can represent these factors. Level of exposure will indicate the degree, duration and/or extent in which the system is in contact with, or subject to, the perturbation. In this regards some of biophysical data can be used to represent this factors such as the closeness of the system to the source of hazards. Houses which are close to river side will have higher level of exposure to flood than those far from the river side. Thus the houses near the river side will be more likely to be in contact with flood. Sensitivity is the reflection of the internal conditions of the system, which determined by environment, socio-economic condition. The young children or the poor for example will be more prone when they expose to the perturbation than adult/rich people. Thus the higher the sensitivity is, the easier to be affected by the perturbation is. Adaptive capacity is represent the "ability of a system to adjust, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences of the perturbation (climate change). The adaptive capacity will be influenced by the level of education, infrastructure condition etc.

Based on the above definition, level of vulnerablity of a system can be assessed based on biophysical, and socio-economic condition of the system representing level of exposure, sensitivity and adaptive capacity. These types of data called as vulnerability indicators are commonly available in statistical data centre such as BPS (Statistical Bureau). The selection of the indicators is subjective depending on the understanding of the causal link between the indicators and their connection with the three factors. As example, some of the data that may be used for defining the vulnerability profile of villages as the following:

1. Level of exposure (LE): Biophysical data such as households living in River Bank, percent of building in River Bank, fraction of rice and agriculture area etc. The data will represent the extent in which the system is in contact with, or subject to climate variability
2. Level of sensitivity (LS): Socio-economic and biophysical data such as data such as Population density, poverty, main source of income and access to drinking water, fraction of waste that can be managed, fraction of green area, drainage system, irrigation facilities etc. Villages with less poor people and have better access to drinking water will be less sensitive to climate variability. For example, if drought occur, village which are rely much on getting

clean water from river or rainfall will be easily affected by the drought. Similarly the villages where most of agriculture land has irrigation facility will be relatively less sensitive to the impact of drought than those without irrigation facilities.

3. Adaptive capacity (AC): Level of education, road infrastructure, electricity, health facilities, community's organization, etc. Villages with higher level of community education would have better adaptive capacity; villages that have strong community's organization would have better adaptive capacity as collaboration among community's member in addressing the problem is stronger.

The selection of indicators that can represent these three factors is subjective depending on the understanding of the causal link between them. This method will allow the local government to evaluate the impact of development on vulnerability or coping range as the implementation of the development program will change the indicators data representing the level of exposure, level of sensitivity and adaptive capacity.

2.3 Approach for Assessing the Vulnerability Profile

To assess the profile of the vulnerability of a particular system, all of the indicators defined above need to be integrated into an index called vulnerability index. There are a number of approaches in developing vulnerability index based on the defined indicators. Some approaches assigning weight into each indicator depending on level of importance of the indicator in shaping vulnerability. The indicators which have same direction in affecting the vulnerability can be grouped into one index. In this case, indicators representing level of exposure and sensitivity will both contribute to the increase of vulnerability. The higher the level of exposure and level of sensitivity, the higher the vulnerability is. On the other hand, indicators representing adaptive capacity will contribute to the decrease of vulnerability. The higher the adaptive capacity, the lower the vulnerability is. Thus the indicators representing level of exposure and sensitivity can be pooled into a single index called sensitivity and exposure index (SEI), and indicators representing the adaptive capacity can be pooled into another index called adaptive capacity index (ACI). Formula for calculating the indices is the following:

$$SEI_i = \sum_{j=1}^{n} w_{ij} * I_{SEij} \text{ and } ACI_i = \sum_{j=1}^{n} w_{ij} * I_{ACij}$$

Where subscript i and j represents the object-ith and indicator-jth respectively and w is weight value for indicator. The vulnerability profile of the system can be defined using the quadrant as shown in Figure 2.2. In this quadrant, objects (e.g. villages) can be grouped into five types as shown in Table 2-1. The two extreme types are the ones have low adaptive capacity and high sensitivity and exposure level will be the most vulnerable (Type 5), while the ones with high capacity index with low sensitivity and exposure index will be least vulnerable (Type 1). Another approach for defining the vulnerability profile of villages is by applying cluster analysis to the indicators and indices used for defining level of exposure, sensitivity, and adaptive capacity (e.g. Lüdeke, *et al.* 2007; O'brien *et al.* 2004).

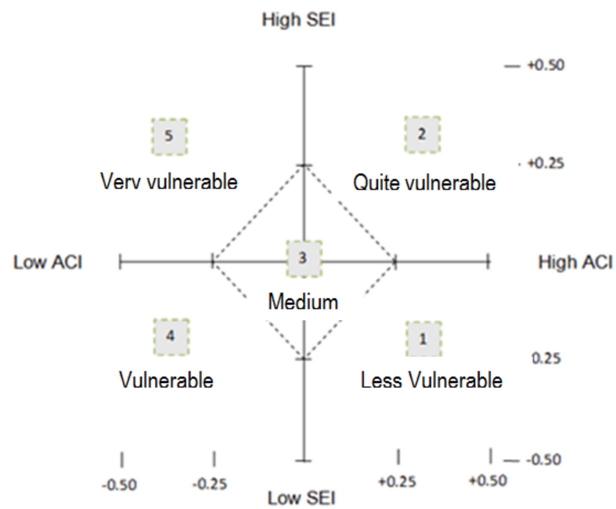


Figure 2-2 Quadrant system for defining vulnerability profile

Table 2-1 Categorization of villages according to their vulnerability profile

Village types according to vulnerability level	Sensitivity and Exposure Index (SEI)	Adaptive Capacity Index (ACI)
Type 5: Very vulnerable	High	Low
Type 4: Vulnerable	Low	Low
Type 3: Medium	Medium	Medium
Type 2: Quite Vulnerable	High	High
Type 1: Less or not Vulnerable	Low	High

2.4 Climate Risk Assessment

Beer and Ziolkowski (1995) define the climate risk as a function of the probability of unexpected climate event to occur and the consequence of the unexpected events if it occurs. If the probability of unexpected events to occur is high and the potential impact on a system is catastrophic, it is said that the system has high level of climate risk. The consequence of the unexpected event would be dependent on the vulnerability of the system. The consequence is expected to be catastrophic if the system being affected by the event is very vulnerable. Following this argument the climate risk can be written as (Jones *et al.* 2004):

Climate Risk (R) = Probability of climate hazard (P) x Vulnerability (V)

Using the above definition, the level of climate risk can be defined using the risk matrix as suggested by Beer and Ziolkowski (1995; Table 2.1). This matrix suggests that if probability of unexpected events (climate hazards) increased in the future due to climate change while the vulnerability remains the same, the level of climate risk will increase, or no change in probability of unexpected events (climate hazards) in the future, but the vulnerability increases, the level of risk will also increase. The change in the probability of the unexpected events may also be defined qualitatively as no change, increase and decrease (Table 2.1).

Table 2-2 Matrix of climate risk as a function of probability of climate hazard and the vulnerability

Probability / Vulnerability	Very Likely (Increase)	Likely (No-change)	Unlikely (Decrease)
Very Vulnerable	*Very High (VH)*	*High (H)*	*Medium-High (M-H)*
Vulnerable	*High (H)*	*Medium-High (M-H)*	*Medium (M)*
Medium	*Medium-High (M-H)*	*Medium (M)*	*Medium-Low (L-M)*
Quite Vulnerable	*Medium (M)*	*Medium-Low (L-M)*	*Low (L)*
Less or not Vulnerable	*Medium-Low (M-L)*	*Low (L)*	*Very Low (VL)*

2.5 Reducing Climate Risk

Reducing the climate risk can be done in two ways, i.e. through mitigation and adaptation. The mitigation is expected to avoid or to minimize climate change (top down) which will affect the probability of climate hazards occurrence, while the adaptation is expected to change vulnerability level. The adaptation actions can be directed to change level of exposure, sensitivity and adaptive capacity. The relationship between mitigation, adaptation, vulnerability and magnitude impact of climate change on a system is shown in Figure 2-3.

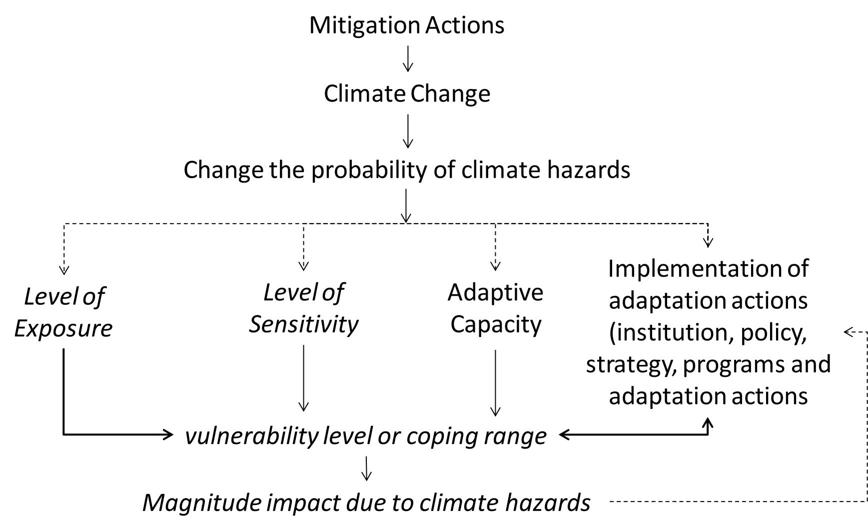


Figure 2-3 Interrelationship between adaptation, mitigation, and vulnerability in reducing magnitude impact of climate change

Change in rainfall pattern, frequency of extreme climate events, temperature increase and sea level rise due to global warming all will have direct impact on the occurrence of climate hazards. Increased frequency, intensity and duration of extreme rainfall will result in increasing floods and landslide events. Prolonged dry season and sea level rise will also increase drought risk and water salinity problems, particularly in the coastal areas. These all will change the probability of unexpected events. Through mitigation, it is expected that the high increase in probability of climate hazards can be avoided.

The increase in climate related disasters may damage infrastructure facilities (e.g. irrigation facilities, drainage system etc), increase crop failure and reduce yield and finally reduce farmers' income etc which in turn increase the vulnerability. Adaptation actions can reduce the vulnerability level either by reducing level of exposure, level of sensitivity and/or adaptive capacity. Adaptation actions such as improvement of spatial plan, reallocation of settlement etc. would change level of exposure. Adaptation actions such as generation of more alternative livelihoods, establishment and improvement of irrigation facilities and drainage system, restoration of catchment area, finding resistant varieties to climate stress etc. may reduce the level of sensitivity. Adaptation actions such as improvement of education facilities and access, establishment of disaster funds, climate insurance policies, strengthening institutional/community capacity in using climate information for climate risk management etc. may increase adaptive capacity. Thus mitigation and adaptation will indirectly and directly reduce the climate risk.

3 ESTIMATING VULNERABILITY INDEX AND LEVEL OF CLIMATE RISK OF VILLAGES AT CITARUM RIVER BASIN

3.1 Estimating Vulnerability Index of Villages in CRB

As discussed above, the vulnerability profile of villages in CRB is defined using a number of selected indicators. The list and description of indicators used to represent level of exposure, level of sensitivity and adaptive capacity of villages in CRB is presented in Table 3-1.

Table 3-1 Indicators used for defining level of exposure (LE), level of sensitivity (LS), adaptive capacity (AC) of villages at CRB and the corresponding weights

No	Biophysical, socio-economic data	Weights	Description of the indicators
A. Data representing Adaptive Capacity of the Villages			
A1	Electricity Facility (FLt)	0.25	Indicating the level of wealth of household. Wealthier families relatively have better adaptive capacity
A2	Education Facility (FPk)	0.30	Condition of education of HH in the village would reflect the ability of community to manage the risk.
A21	*Nursery School*	*0.07*	
A22	*Elementary School*	*0.13*	
A23	*Junior High School*	*0.20*	
A24	*Senior High School*	*0.27*	
A25	*University*	*0.30*	
A3	Health facility (FKs)	0.30	Condition of health system is required to ensure good access for community to have immediate treatments whenever strike by hazards
A31	*Puskesmas*	*0.20*	
A32	*Polyclinic*	*0.30*	
A33	*Posyandu*	*0.20*	
A34	*Midwifes Clinic*	*0.10*	
A35	*Med. Doctor Clinic*	*0.20*	
A4	Road Infrastructure (IJ)	0.15	Condition of transportation system is needed to ensure safe and timely distribution of aid, evacuation etc.
B. Data representing level of exposure sensitivity of villages			
B1	Number of household living in River Bank (KBs)	0.10	Indicating the closeness of the settlement and properties to source of hazards (level of exposure). Villages in which many HH live near the river side will have high level of exposure to flood
B2	Number of Building in River Bank (BGs)	0.10	
B3	Source of Drinking Water (SAM)	0.20	Indicating the access of HH to drinking water. HH equips with piping system will be less sensitive than that without piping system. When drought occurs, HH with piping system may still have access to drinking water making them less sensitive to drought
B31	*- Piping system (PDAM)*	*0.25*	
B32	*- Electric Pump*	*0.50*	
B33	*- Well*	*0.75*	
B34	*- Spring*	*0.75*	
B35	*- Rainfall and Others*	*1.00*	
B4	Population density (KPdk)	0.20	Indicating level of exposure. Number of people will be in contact with hazard will be higher in villages with higher population density
B5	Poverty (KPs)	0.20	Indicating ratio between poor HHs and total HHs. Villages

			with higher ratio is more sensitive
B6	Fraction of lowland rice area (LSw)	0.05	Indicating fraction of areas of villages which are sensitive to climate variability and climate change
B7	Fraction of agriculture area (LLp)	0.05	
B8	Main Source of Income (SMP)	0.10	Indicating the sensitivity of HH income to climate hazards. Villages where main source of the income is very climate-dependent such as agriculture will be more sensitive.

It should be noted that, the indicators selected for defining the exposure, sensitivity and adaptive capacity depending on the availability of data and knowledge in understanding connection between the data and level of exposure, sensitivity and adaptive capacity as well as understanding their connection with climate variability and climate change. Thus the above indicators can be expanded as the data available. For example, other biophysical or environmental data such as ratio between waste production and capacity to manage the waste may represent the sensitivity. If production of waste is much higher than capacity to manage, the unmanaged waste may be dumped into river or drainage canal. This condition make the village become more sensitive to the change of rainfall intensity. Slight increase in rainfall may be enough to cause flood in the village since the capacity of river or canal in flowing the excess water decreases due to waste blocking. Availability of alternative livelihoods may reduce the sensitivity as community has more options for supporting their live in the case their rainfall-dependent income sources affected by the hazards. Thus the reliability of the vulnerability index will be dependent on the availability and reliability of data representing the level of exposure, sensitivity and adaptive capacity.

3.1.1 Estimating Adaptive Capacity Index of Village

As shown in Table 3-1, the Adaptive Capacity Index (ACI) is developed using four main indicators (A1, …, A4). Each indicator is scored. The scoring value of Indicator A1 is the percentage of household in *village* that uses electricity facility. This indicator represents the level of wealth of communities of the *Village* s. Indicator A2 is education which may represent the capacity of community in the *Village* s in managing the risk. The higher the education is the better their capacity in managing the risk is. This indicator consists of five sub-indicators namely number of Nursery (N), elementary (E), and junior high schools (J) at *village* level, senior high school at Sub-District level (H) and University at District Level (U). The scoring value of I_{A2} in each *Village* was calculated using the following formula:

$$I_{A2i} = 1/P_i * (0.07*N_i+0.13*E_i+0.20*J_i) + 1/P_{ij}*(0.27*S_j)+1/P_{ik}*(0.30*U_k)$$

Where P_i, P_{ij}, and P_{ik} are the population size of *Village -i*, Sub-District-*j* of *Village -i*, and district-*k* of *Village -i* respectively.

Indicator A3 is health facility which represents access of community to health facilities. The better the health facility in the *Village* is the higher the capacity of the *Village* is. This indicator is further divided into 5 sub-indicators namely number of Polyclinic (Pl), Child Community Services (*Posyandu, Ps*), Health Community Services (*Puskesmas, Pk*), Midwifes Clinic (B) and Doctor Clinics (D). All the values of the sub-indicators were divided by population size of the corresponding *Village*. Accessibility of the health facilities (A) was also taken into account in calculating the health facility score. The scoring value of I_{A4} in each *Village* was calculated using the following formula:

$$I_{A4i} = \frac{1}{P_i}\left\{0{,}3\times\left(\frac{\left[{}^{PI_i}/_{P_i}\right]+Ap_i}{2}\right) + 0{,}2\times\left(\frac{\left[{}^{Ps_i}/_{P_i}\right]+Ap_i}{2}\right) + 0{,}2\times\left(\frac{\left[{}^{Pk_i}/_{P_i}\right]+Ap_i}{2}\right) + 0{,}1\times\left(\frac{\left[{}^{B_i}/_{P_i}\right]+Ap_i}{2}\right) + 0{,}2\times\left(\frac{\left[{}^{D}/_{P_i}\right]+Ap_i}{2}\right)\right\}$$

Where P_i is the population size of *Village-i.*

Indicator A4 is main road surface type. Villages were scored based on dominant type of the road infrastructure. If the dominant road infrastructure in the villages was made from aspalt, the score will be equal to 1 (Table 3-2).

Table 3-2 Scoring value of the road indicator

No	Type of road surface	Score (indicator value)
1	Others	0.25
2	Soil	0.50
3	Gravel	0.75
4	Asphalt	1.00

With exception of Indicator A4, all score values of the indicators were converted into values ranging from 0 to 1 with interval of 0.1 using percentile of the data distribution. Thus, if the calculated score value less than 10^{th}Percentile (P10), then it converted into 0.1, if it is between P10 and P20, it becomes 0.2, if it is between P20 and P30, it becomes 0.3, if it is between P30 and P40, it becomes 0.4, if it is between P40 and P50, it becomes 0.5, if it is between P50 and P60, it becomes 0.6, if it is between P60 and P70, it becomes 0.7, if it is between P70 and P80, it becomes 0.8, if it is between P80 and P90, it becomes 0.9, and if it is more than P90, it becomes 1.0. Data used for defining P10, .., P90 is 2005. Thus condition in 2005 was used as baseline.

The formula to calculate the ACI is the following:

$$ACI_i = \sum_{j=1}^{5} w_{ij} * I_{Aij}$$

Where subscript-i^{th} represents *Village* -i^{th} and w_{ij} is weight value for indicator A-j^{th} of *Village*-i^{th}. The selection of the weight values was subjective, based on understanding and knowledge of experts on relative important of the indicators in determining the level of capacity. With this formula, the higher the capacity index value is, the higher the capacity of the *Village* is.

3.1.2 Estimating Sensitivity and Exposure Index of Village

Similar with the Adaptive Capacity Index (ACI), the SEI was also developed using the same approach. There eight main indicators (B1, …, B8) representing level of exposure and sensitivity are defined in Table 3-1. Indicators B1 is percent of household in the *Village* living in the river bank. Indicator B2 is number of building situated in the river banks.

Indicator B3 is production capacity of Drinking Water Company (PDAM) in supplying water to the *village*. *Village* where most of the community gets drinking water from PDAM will be less vulnerable to drought impact as the PDAM normally still can supply enough drinking water irrespective of season (dry or wet).

Table 3-3 Indicator value based on main of source drinking water

No	Source of main drinking water	Score (Indicator value)
1	PDAM/ Pipe water	0.25
2	Electric Pump	0.50
3	Well, Spring	0.75
4	Rainfall/ Others	1.00

Indicator B4 is population density in which the higher the population density the higher level of the exposure of the people to hazard. This puts the *village* into more vulnerable *village*. Indicator B5 is number of poor household. Values of this indicator are normalized with population size of the *village*. Indicator B6 and B7 are fraction of low land rice and agriculture area in the *village* respectively. The *Village*s that have large area of low land rice and agriculture land will be more vulnerable since rice and agriculture crops are easily affected by climate hazards. The higher these value the more vulnerable the *Village*.

Indicator B8 is main income source of community in the village. For *Village*s where main source of income of the community is strongly influenced by or very sensitive to climate variability and climate change will have high sensitivity score. The values of the indicator by main source of incomes are presented in Table 2. *Village* in which agriculture is the main source of income of the community, the scoring value will be 1.00.

Table 3-4 Indicator value according to types of main income source of community in the Village

No	Main source of income	Score (Indicator value)
1	Agriculture	1.00
2	Mining and processing industries	0.75
3	Trading, transportation and communication business etc	0.50
4	Services	0.25

Similar to ACI, all score values of the indicators were converted into values ranging from 0 to 1 with interval of 0.1 using the percentile except for indicators B3 and B8. The formula to calculate the SEI is the following:

$$SEI_i = \sum_{j=1}^{5} w_{ij} * I_{Bij}$$

Where subscript-i^{th} represents *Village* -i^{th} and w_{ij} is weight value for indicator B-j^{th} of *Village* -i^{th}. The selection of the weight values was subjective, based on understanding and knowledge of experts on relative important of the indicators in determining the level of capacity. With this formula, the higher the index, the more vulnerable the *Village* is.

3.2 Defining Level of Climate Risk of Villages

As described above, the level of climate risk of villages in the future is defined based on change of probability of unexpected events (extreme climate events) from baseline and vulnerability level of the villages in 2011 (see Table 2-1). Thus in this analysis, the vulnerability level of villages in the future is assumed to be the same as the present one. Types of unexpected events being considered in this study is flood and drought occurrence. To assess the change of the probability of the unexpected events in the future, we determined the rainfall threshold causing flood and drought using historical flood and drought data occurred in agriculture area at district level from 1989-2010 from the Directorate of Plant Protection. This data is used since the length of record is more than 20 years and main source of economic activities of communities are still agriculture. The step of analysis is described in Faqih et al. (2013). The results of analysis are presented in Figure 3-1 and 3-2. The projection of the drought and flood probabilities is given for four emission scenarios, i.e. RCPs 2.6, 4.6, 6.0 and 8.5 (Moss et al., 2010).

Figure 3-1 suggests that the probability of WS rainfall causing floods is expected to increase mostly over upper area of CRB, with more significant increase of probability are found in the western part of Bandung. These are found mostly in RCP4.5 and RCP8.5 scenarios. More frequent rainfall causing floods in the upper part of CRB could potentially increase the risks not only in the region but also in the middle and lower part of CRB. Figure 3-2 shows that the occurrence of drought in the upper area of CRB will be more frequent in the future. The probabilities of the rainfall causing droughts are also found to increase in the lower part of CRB, especially in Bogor, Karawang and Bekasi.

The level of climate risk of the villages is derived by overlaying the change of probability of the unexpected climate events (decrease, no change or increase compare to current probability) and the vulnerability maps of 2011. Thus this information informs the change of climate risk of villages in the future assuming no change in the vulnerability. To reduce the risk, the vulnerability should be lowered and the priority locations for the implementation of adaptation actions should be given to villages in which at present they already pose high climate risk and in the future they will pose higher climate risk, while the least priority is given to villages that have very low climate risk at present and lower climate risk in the future.

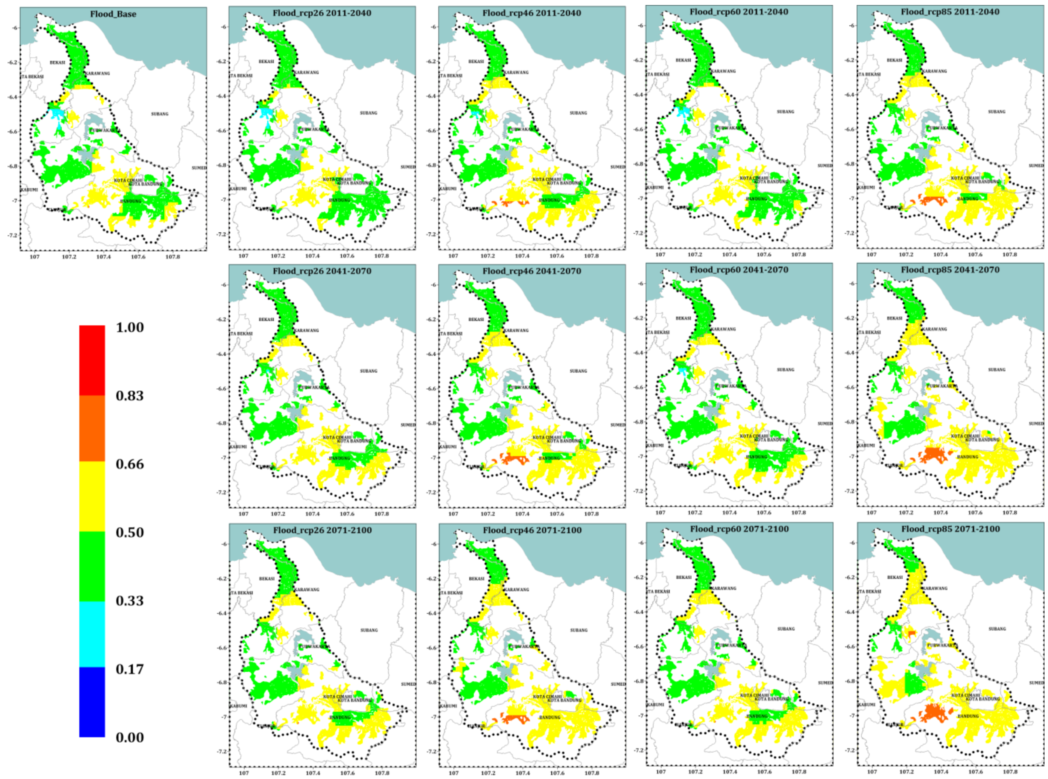


Figure 3-1 Probability of rainfall causing floods (Faqih et al., 2013)

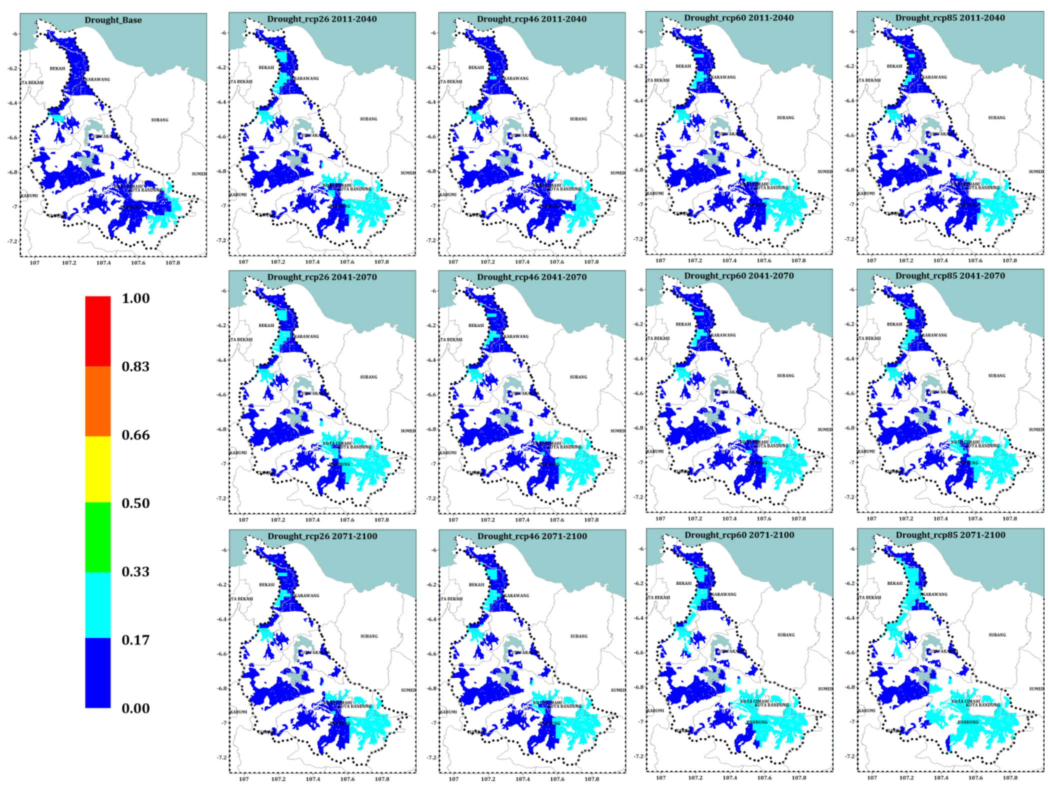


Figure 3-2 Probability of rainfall causing droughts (Faqih et al., 2013)

4 VULNERABILITY AND CLIMATE RISK PROFILE OF VILLAGES AT CITARUM RIVER BASIN

4.1 Vulnerability Profile of Villages at CRB

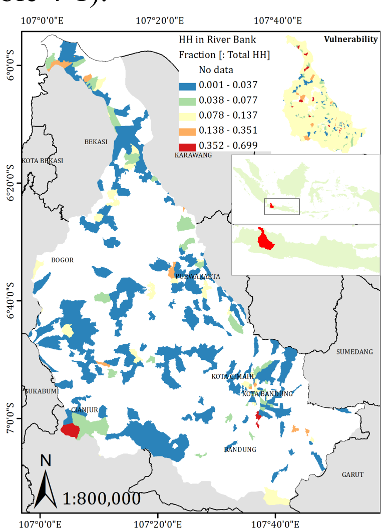
The vulnerability profile of villages in CRB was assessed using data of 2005 and 2011 from the Bureau of Statistics. All indicators defined in Table 3-1 are available for both years except for poverty (B5). In the analysis the poverty of 2011 is assumed to be the same as that of 2005. The condition of the indicators of all villages representing level of exposure, sensitivity and adaptive capacity is described in the following sections.

4.1.1 Level of Exposure

Household Living in River Bank. There are about 1179 villages in the CRB. In 2005 about 71.63 % of the villages have no families (household) living near the river side. In 2011, it decreased slightly to 70.63% (Table 4-1). This suggests that between 2005 and 2011, there were new households established their settlement near the river side. In general in most of villages with river side-HHs, fraction of HHs live near the river side is less than 3.7%. However, in 2011 there are 7 villages where more than 20% of their households live near the river side namely Wangunjaya in Cianjur District (57%), Andir (38%), Ciparay (35%), Arjuna (24%) and Majalaya (21%) in Bandung District, Pantai Mekar (27%) in Bekasi District and Tamelang (21%) in Karawang District (see Figure in the right hand side of Table 4-1).

Table 4-1 Percentage of villages in CRB according to fraction of HHs live near the river side in 2005 and 2011

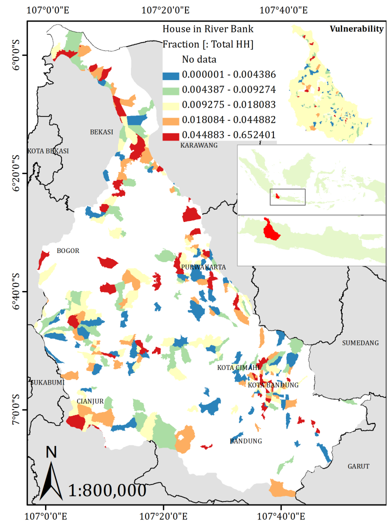
HH in river Bank (Fraction)	Percentage of Village	
	2005	2011
0	71.63	70.96
≤ 0.037	19.73	21.00
0.037 - 0.077	3.56	3.47
0.077 - 0.137	2.79	2.54
0.137 - 0.351	1.27	0.85
> 0.352 [0.699]	0.25	0.17



Building in River Bank. In 2005 about 72.21 % of the villages have no buildings established near the river side. In 2011, it decreased slightly to 71.71% (Table 4-2). In general in most of villages with river side-buildings, fraction of building established near the river side is less than 4.5%. However, in 2011 there are 6 villages where more than 15% of their buildings established near the river side namely Andir (37%), Gedang (19%), Taman Sari (19%) in Bandung District, Sindanglaya (20%) in Purwakarta District, Tamelang (18%) in Karawang District and Wangunjaya (15%) in Cianjur District (see Figure in the right hand side of Table 4-2).

Table 4-2 Percentage of village based on number of building in River Bank in 2005 and 2011

Building in River Bank (Fraction)	Percentage of Village	
	2005	2011
0	72.21	71.71
< 0.0044	5.63	6.41
0.0044 - 0.0093	5.63	4.79
0.0093 - 0.0181	5.46	6.58
0.0181 - 0.0448	5.46	5.21
> 0.0448 [0.652]	5.63	5.30



Population Density. *Most villages* in CRB have population density of less than 25 persons/ha (Table 4-3). However, between 2—5 and 2011 there is a significant increase in population density in some of villages (Figure 4-1). Villages with the highest population density is Babakan Asih village (633 person/ha) in Bandung District.

Table 4-3 Percentage of village based on population density (persons per ha) in 2005 and 2011

Population Density [person/ha]	Percentage of Village	
	2005	2011
≤ 25	62.49	57.61
25 - 75	23.79	25.56
75 - 125	5.03	6.84
125 - 150	1.96	1.97
> 150 [977]	6.73	7.78

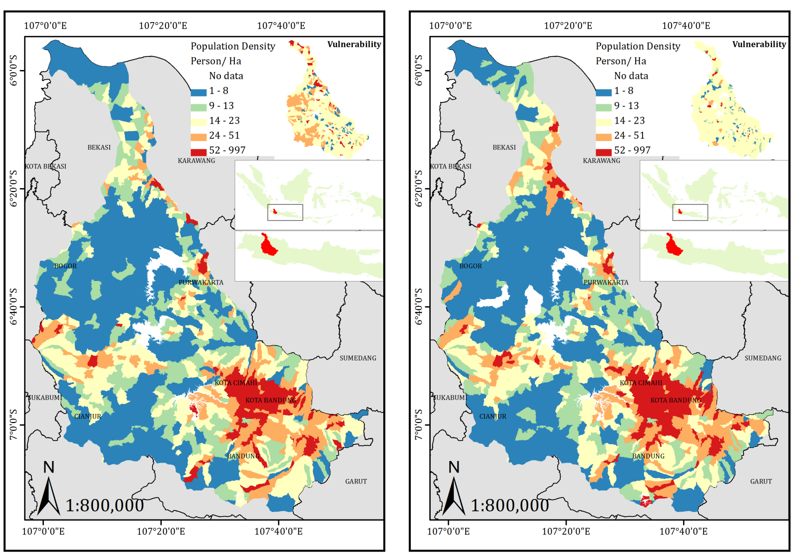


Figure 4-1 Classification of village by population density in 2005 (left) and 2011 (right)

4.1.2 Sensitivity

Source of Drinking Water. Majority of HHs in villages in CRB still rely on wells (electric pump and well). In 2005 more than 87% of HH get clean water from wells, but in 2011 it decreased to 65% (Table 4-4). Some of these HHs changed their source of water from wells to spring water particularly in the middle and upper part of CRB (Figure 4-2). Based on interview, many of wells get dry (have no water) during dry season particularly in the upper and middle part of the CRB.

Table 4-4 Percentage of village based on source of drinking water in 2005 and 2011

Source of Drinking Water	Percentage of Village	
	2005	2011
Piping system/bottled water	12.11	14.96
Well with Electric Pump	15.94	23.25
Well with manual	71.10	42.31
Spring	0.85	17.69
River/ Lake	0.00	0.51
Rainfall	0.00	0.60
Others	0.00	0.68

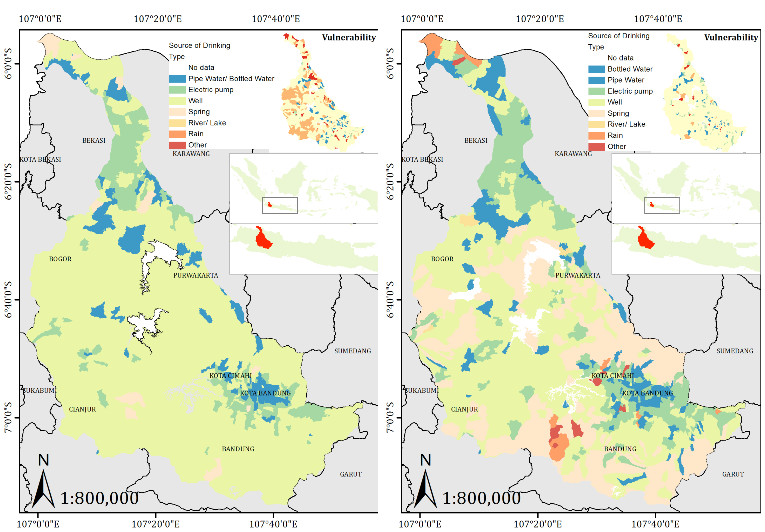
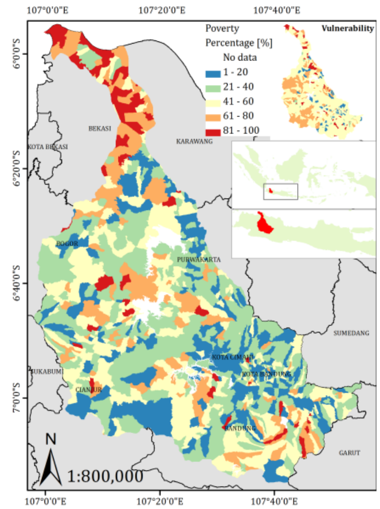


Figure 4-2 Classification of village based on source of clean/drinking water 2005 (left) and 2011 (right)

Poverty Index. Number of poor HH in villages of CRB is still quite high. Ratio of poor HH to total HHs in 55% of villages in CRB is less than 0.40, and in the remaining villages it is more than 0.40 (Table 4-5). About 5% of villages, mostly located in the lower part of CRB, have the ratio of more than 0.80 (see Figure in the right hand side of Table 4-5).

Table 4-5 Percentage of village based on poverty index

Poverty Index (Fraction)	Percentage of Village
≤ 0.20	21.78
0.20 - 0.40	33.56
0.40 - 0.60	26.39
0.60 - 0.80	13.41
0.80 - 1.00	4.87



Fraction of Lowland Rice Area. Lowland rice is agriculture commodity that requires much water. The decrease in rainfall will have serious impact on lowland rice. In this case, villages where large fraction of their areas dominated by lowland rice area would be more sensitive than those with low fraction. In 2005, most of villages in CRB have rice paddy area of less than 22% of the total area (Table 4-6). In a few villages, area of lowland rice is still dominant, i.e. more than 71%, particularly in villages located in the downstream. Between 2005 and 2011 there was no much change in the area of lowland rice (Figure 4-3).

Table 4-5 Percentage of village based on fraction of lowland rice area in 2005 and 2011

Fraction of Lowland Rice Area	Percentage of Village	
	2005	2011
≤ 0.22	40.64	40.30
0.20 - 0.36	15.75	16.34
0.36 - 0.51	16.09	14.99
0.51 - 0.70	14.23	14.14
> 0.70	13.89	13.97

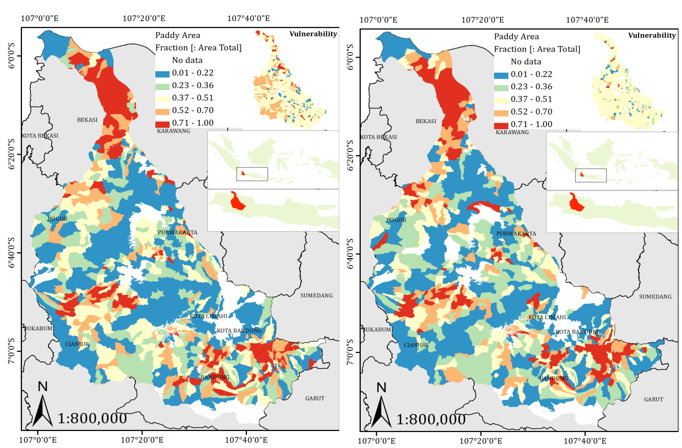


Figure 4-3 Classification of village based on fraction of lowland rice area in 2005 (left) & 2011 (right)

Fraction of Agriculture Area. In 2005, fraction of agriculture area is most of villages in CRB is less than 14% (Table 4-7). In 2011, the fraction in villages located in the middle and upper part of CRB increased quite significant (Figure 4-4). In 2005, percentage of villages with fraction of agriculture land more than 40% was about 11% and in 2011 it increased to about 34%. This indicates that the agriculture area in the middle and the upper part of CRB has expanded (Figure 4-4). The expansion of this agriculture land took place in forested land causing deforestation. The decreased in forest area may increase vulnerability of the villages as forest plays important role in buffering climate extreme events. Villages with less forest cover will be relatively more sensitive to extreme rainfall than that with larger forest cover. With less forest cover, rainfall water will directly flow as surface runoff and expose the downstream area to higher flood risk. Similarly during long dry season, the region will also be exposed to high drought risk as capacity of soil in retaining water is low.

Table 4-6 Percentage of village based on fraction of agriculture area in 2005 and 2001

Fraction of Agriculture Area	Percentage of Village	
	2005	2011
≤ 0.14	66.75	44.93
0.14 - 0.25	10.83	9.21
0.25 - 0.40	11.08	11.51
0.40 - 0.61	8.10	15.69
> 0.61	3.24	18.16

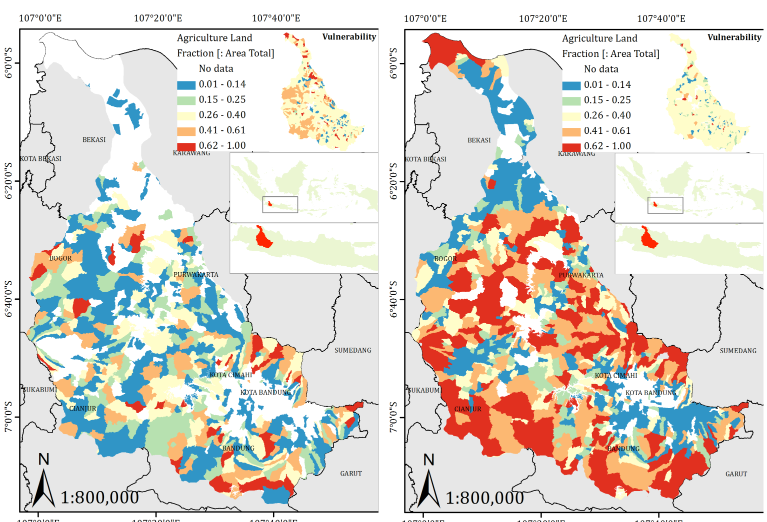


Figure 4-4 Classification of village based on agriculture area fraction in 2005 (left) and 2011 (right)

Source Main Income. The source of main income of communities in most of villages in CRB still relies on agriculture (Table 4-8). Between 2005 and 2011, the source of main income in some villages has shifted from agriculture to non-agriculture, particularly villages in cities or in districts with rapid industrial developments. Rapid industrial development is in Kerawang, Bandung and Garut districts (Figure 4-5). While in Bandung City, the source of main income is from services. Villages with agriculture as source of main income are more sensitive to climate variability and climate change, therefore they are considered to be more vulnerable to climate change.

Table 4-7 Percentage of village based on source of main income in 2005 and 2011

Source of Main Income	Percentage of Village	
	2005	2011
Agriculture	68.12	66.32
Mining	0.00	0.77
Industry	6.31	11.45
Trading, Restaurant	9.72	6.75
Services	14.49	11.62
Others	1.36	3.08

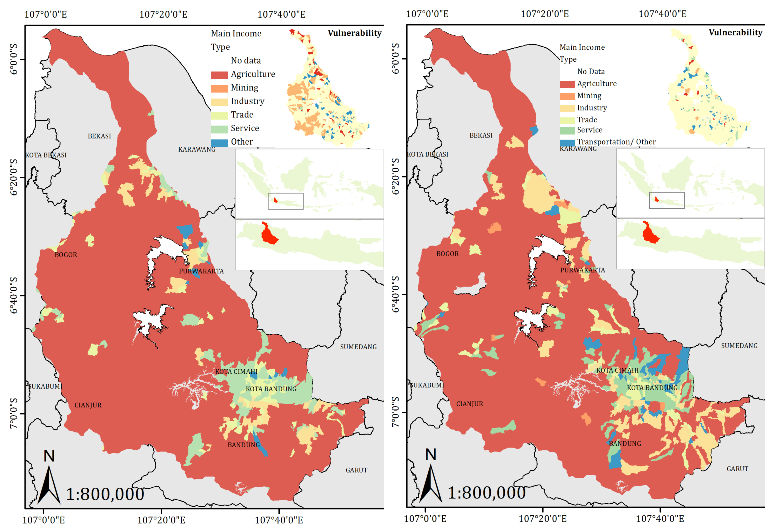


Figure 4-5 Classification of village based on source of main income in 2005 (left) and 2011 (right)

4.1.3 Adaptive Capacity

Household with Electricity. In 2005, percentage of villages in which most of the HH already using electricity was still about 55%, and in 2011 it increased sharply to 91% (Table 4-9). Rapid increase in number of HH using electricity was mainly in cities such as Bandung and Cimahi Cities. However, in 2011there are still villages in the districts of CRB having percentage of HH with electricity below 50% (Figure 4-6). These villages are Cigondewah Kaler, Cihawuk, Kebon Pisang, and Pasir Biru in Bandung District; Cipangeran, Cibitung, and Kertajaya in Bandung Barat District; Cipayung, and Sukakarya in Bekasi District; Buanajaya, and Tanjung Rasa in Bogor District; and Cibanggala, Situhiang, Sukasirna, and Cirama Girang in Cianjur District. Villages with low fraction of household with electricity may indicate poor economic condition of the community and this reflects low adaptive capacity.

Table 4-8 Percentage of village based on number of household using electric in 2005 and 2011

Fraction of HH using Electricity	Percentage of Village	
	2005	2011
≤ 0.20	1.28	0.26
0.20 - 0.40	6.39	0.85
0.40 - 0.60	12.70	1.54
0.60 - 0.80	23.79	5.38
0.80 - 1.00	55.84	91.97

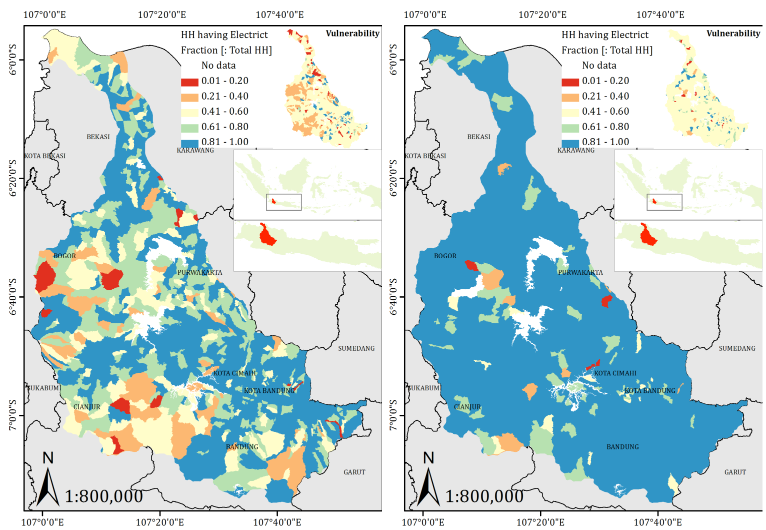


Figure 4-6 Classification of village based on number household using electric in 2005 (left) and 2011 (right)

Education Facility. Between 2005 and 2011, there is an increase in term of number of villages with low education facilities, i.e. from 22.17% to 35.38%, while number of village with high education facilities decreased (Table 4-10). This suggests that number of education facilities do not increase following the rate of population growth, particularly in the upstream and downstream area of the CRB (Figure 4-7). Villages with low education facilities will relatively have low adaptive capacity compare to the one with good education facilities. Ideally the indicator used to represent adaptive capacity is level of education of communities not number of schools. However this data is not available for all districts, therefore the number of schools was used instead of education level.

Table 4-9 Percentage of village based on availability of education facilities in 2005 and 2011

Education Facilities	Percentage of Village	
	2005	2011
≤ 0.00010	22.17	35.38
0.00010 - 0.00015	38.70	37.01
0.00015 - 0.00020	23.87	20.26
0.00020 - 0.00025	9.12	5.38
> 0.00026 [0.00075]	6.14	1.97

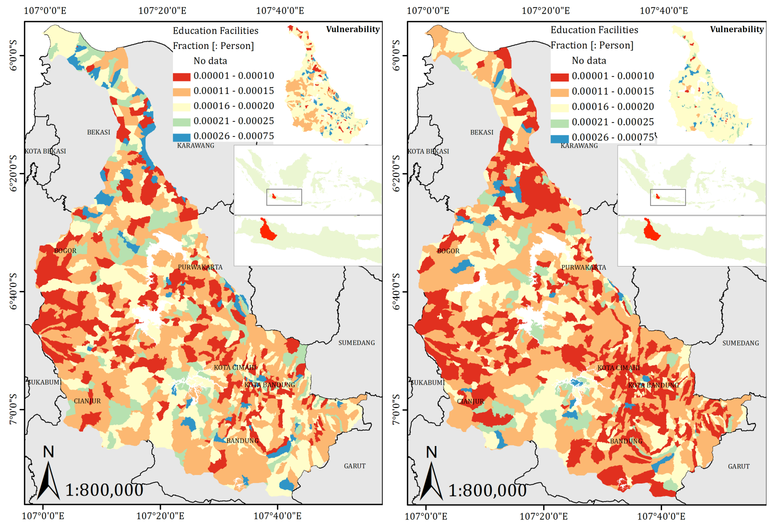


Figure 4-7 Classification of village based on availability of education facilities in 2005 (left) and 2011 (right)

Health Facility. Different from education facilities, the health facilities in the villages has improved in 2011 compare to 2005 (Table 4-11). The improvement of health facilities was quite rapid in the upper and middle of the CRB (Figure 4-8). The condition of health facility in village can reflect the adaptive capacity. The easiness of communities to access health facilities and services will improve the adaptive capacity, especially during extreme climate years.

Table 4-10 Percentage of village based on availability of health facilities in 2005 and 2011

Health Facilities	Percentage of Village	
	2005	2011
≤ 0.00027	32.99	24.10
0.00027 - 0.00035	28.73	27.44
0.00035 - 0.00047	27.02	29.06
0.00047 - 0.00058	7.67	12.14
> 0.00058 [0.00106]	3.58	7.26

Road Infrastructure. Condition of transportation infrastructure in villages of CRB has improved recently. In 2011, more villages already have good road infrastructure (road with asphalt), while number of roads with gravel or soils have decreased compare to condition in 2005 (Table 4-12). Improvement of road infrastructure of villages occurred in most of the cities and districts in CRB (Figure 4-9). Villages with better road infrastructure will relatively have better adaptive capacity. Road will ease the community to evacuate whenever hazard occurs, thus this data can reflect adaptive capacity of the villages.

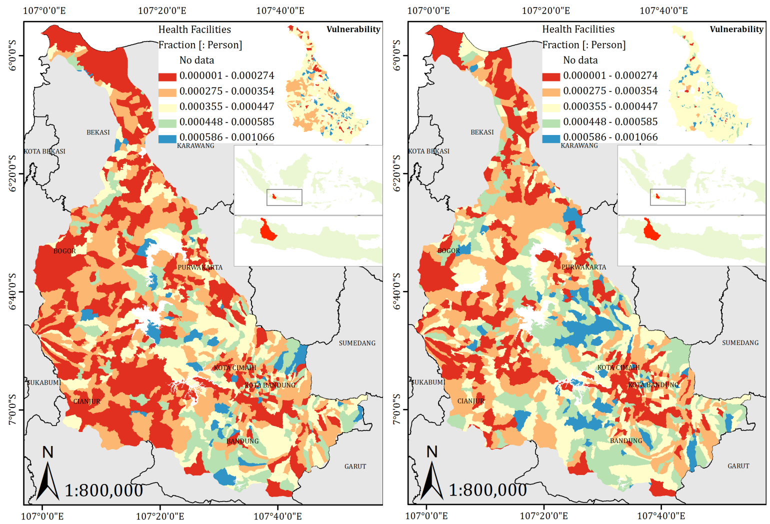


Figure 4-8 Classification of village based on availability of health facility in 2005 (left) and 2011 (right)

Table 4-11 Percentage of village based on type of road surface in 2005 and 2011

Type of Road Surface	Percentage of Village	
	2005	2011
Asphalt	78.31	84.17
Gravel	19.47	14.88
Soil	2.22	0.94
Others	0.00	0.00

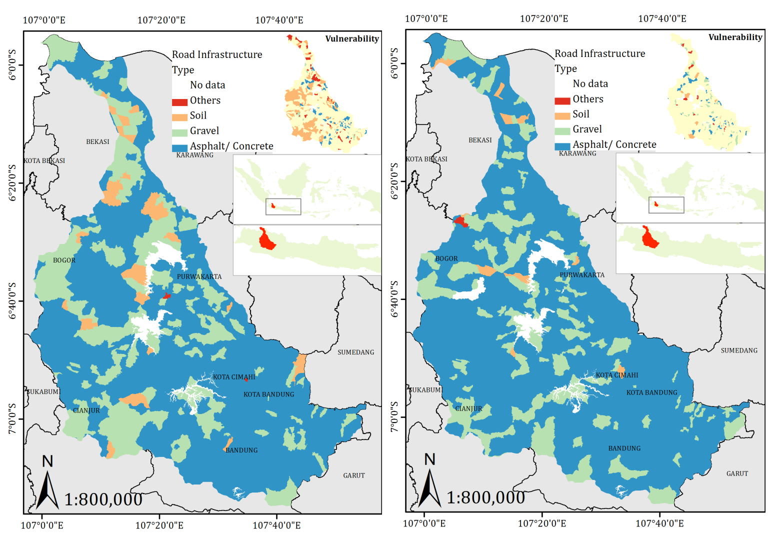


Figure 4-9 Classification of village based on type of road surface in 2005 (left) and 2011 (right)

4.2 Vulnerability Profile of Villages at CRB

Vulnerability profile of villages in CRB can be divided into five types according to the SEI and ACI as defined in Table 2-1, Figure 2-2 above. It was found that in 2005 the vulnerability of most of the villages in CRB fall under category medium (Type 3) and in 2011 it was dominated by Type 2 (Table 4-12). This suggests that the sensitivity and exposure index of many villages has increase between 2005 and 2011, but the adaptive capacity index also increased. Figure 4-11 showed that in general factor causing the increase in SEI of the villages was the increase in difficulties in accessing clean water (SAM), while that causing the increase in ACI was the improvement of access to electricity (FLt).

Table 4-12 Percentage of village based criteria of vulnerability in 2005 and 2011

	Percentage of village	
Vulnerability Profile	2005	2011
Type 1: SEI Low - ACI High (Not Vulnerable)	22.93	16.88
Type 2: SEI High - ACI High (Quite vulnerable)	24.04	51.33
Type 3: SEI Medium - ACI Medium (medium)	44.16	29.56
Type 4: SEI Low - ACI Low (Vulnerable)	5.03	0.77
Type 5: SEI High - ACI Low (Very Vulnerable)	3.84	1.46

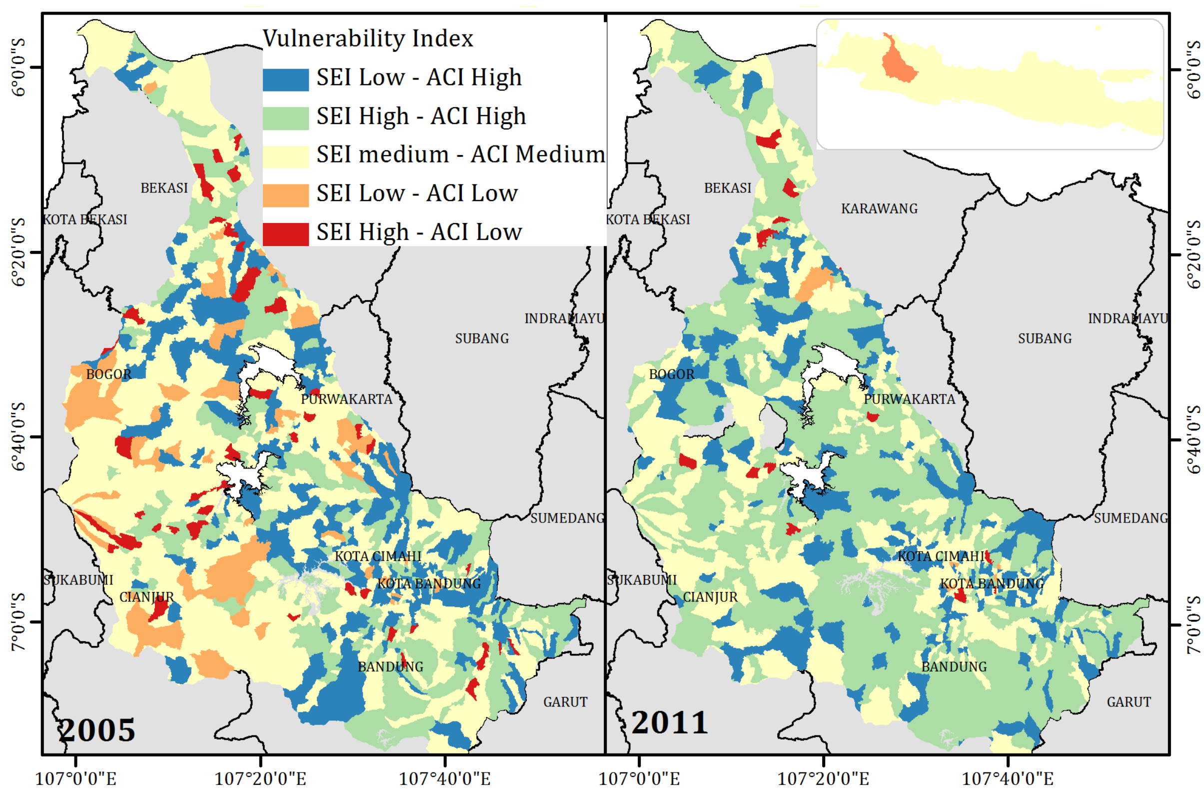


Figure 4-10 Vulnerability level of villages in CRB in 2005 (left) and 2011 (right)

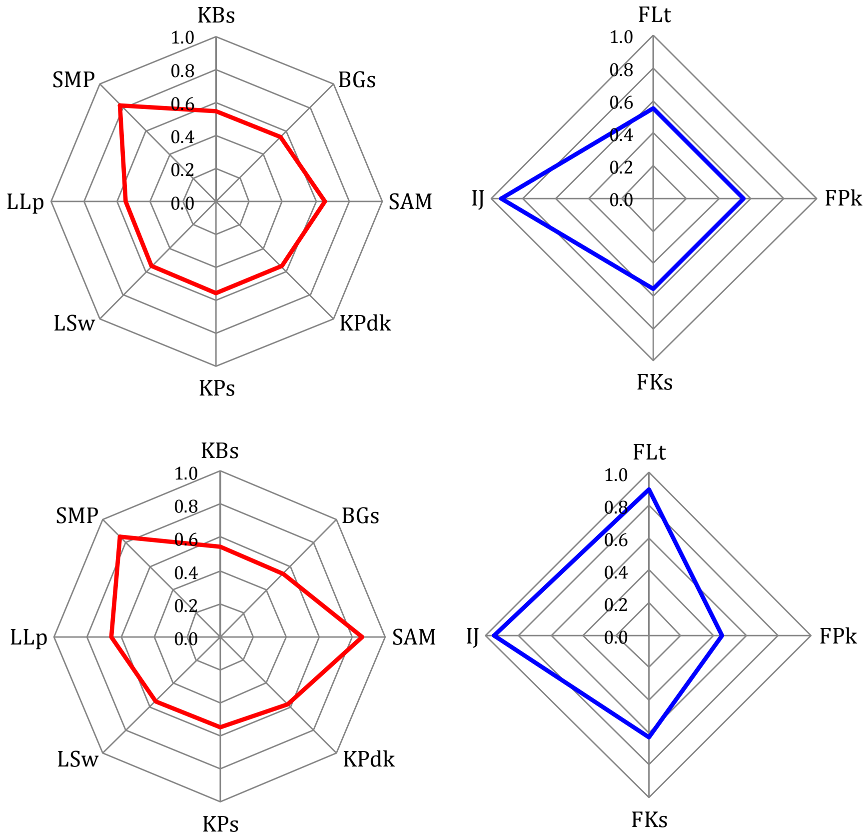


Figure 4.11. Spider Graph showing conditions of indicators of SEI and ACI in 2005 (above) and 2011 (Below)

Furthermore, number of villages under very vulnerable category also decreased, i.e. about 45 villages (3.84%) in 2005 and 17 villages (1.46%) in 2011 (Table 4-13). Nevertheless, a few villages which were previously less/not vulnerable in 2005 became more vulnerable in 2011 as shown Figure 4-10.

Table 4-13 Villages with very vulnerability in CRB

2005		
District	Sub District	Villages
Bogor	Jonggol	Sukasirna
Cianjur	Cianjur	Sayang
	Cibeber	Salagedang
	Cugenang	Sukamanah
	Gekbrong	Songgom
	Karangtengah	Sindangasih
	Mande	Bobojong

2011		
District	Sub District	Villages
Cianjur	Bojongpicung	Hegarmanah
	Cikalongkulon	Cinangsi
		Gudang
	Sukaresmi	Ciwalen
Purwakarta	Sukatani	Cibodas
Karawang	Klari	Cibalongsari
Bekasi	Cikarang Timur	Cipayung

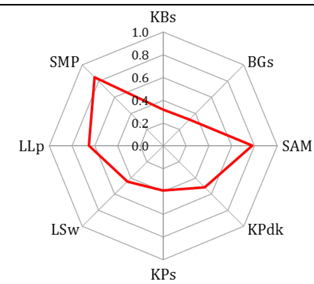
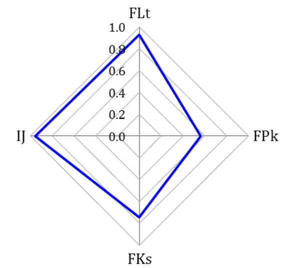
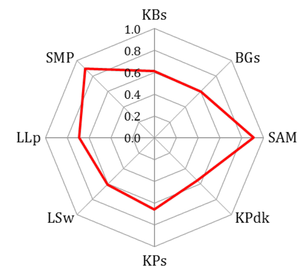
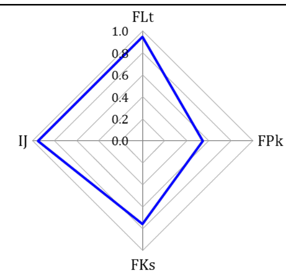
	Sukaluyu	Babakansari
		Sukasirna
		Tanjungsari
	Sukaresmi	Cibanteng
	Warungkondang	Bunikasih
		Bunisari
		Ciwalen
		Sukawangi
Bandung	Baleendah	Malakasari
	Banjaran	Ciapus
	Majalaya	Majakerta
		Neglasari
		Padaulun
	Pacet	Mandalahaji
	Pameungpeuk	Bojongkunci
	Paseh	Cijagra
Purwakarta	Bojong	Sindangsari
	Maniis	Pasirjambu
	Plered	Cibogo Girang
	Pondok Salam	Pondokbungur
	Sukatani	Cibodas
		Cijantung
	Tegal Waru	Pasanggrahan
Karawang	Ciampel	Mulyasari
		Parungmulya
	Rengasdengklok	Dewisari
	Telukjambe Timur	Purwadana
		Sukaharja
Bekasi	Cibarusah	Sirnajati
	Karangbahagia	Karangmukti
	Kedungwaringin	Bojongsari
	Pebayuran	Karangjaya
		Kertajaya
	Sukakarya	Sukamakmur
Bandung Barat	Cihampelas	Citapen
		Pataruman
	Sindangkerta	Puncaksari
Bandung City	Ujung Berung	Pasir Wangi
	Kedungwaringin	Bojongsari
	Pebayuran	Bantarjaya
		Karangsegar
Bandung City	Babakan Ciparay	Babakan Ciparay
		Cirangrang
		Margahayu Utara
		Margasuka
	Batununggal	Binong
	Bojongloa Kaler	Babakan Asih
	Cibeunying Kaler	Cigadung

To understand what main factors causing the level of vulnerability of the villages, all the indicators are presented in the form of spider graphs as shown in Table 4-14. Table 4-14 shows main factors contributing to the vulnerability in villages with high Sensitivity and Exposure Index (SEI) are main source of income (SMP), household live near river bank (KBs), building near river bank (BGs), and source of drinking water (SAM) and those with low adaptive capacity are household with limited access to electricity (FLt), lack of education (FPk), and health facility (FKs). Thus the vulnerable villages are characterized by limited access to clean water particularly during dry season, many households and buildings near the river side, main economic activities still dependence on agriculture, limited access to electricity, education, and health facilities. In this regards, the adaptation action should be directed to increase access to water, to generate more income alternatives and to improve access to electricity, health, and education facilities. It should be noted that even villages with low SEI, they still face problem in accessing clean water and getting other alternative livelihood activities outside agriculture.

The result of this analysis should be used with cautions as there are a number of critical indicators contributing to vulnerability which were not taken into account in this analysis. Some of important indicators likely available and should be used for the refining the SEI particularly the ones related to water resource management include (i) level of exposure to flood considering the position of villages in the river stream (upstream to the downstream), (ii) mean of elevation and rainfall pattern of the villages for correcting level of sensitivity of drinking water availability to climate anomaly as water supply mainly from wells, river and spring will be affected by the elevation of the village and those from rainfall will be affected by rainfall pattern and season characteristics of the region, (iii) capacity of drainage system, (iv) fraction of area with irrigation facilities, (v) ratio between waste production and waste management (fraction of waste that could be managed), (vi) poverty, and (vii) dependence ratio. Data for refining the ACI may include human and social capital such as (i) percentage of population by level of education, (ii) the presence of community organizations, (iii) availability of emergency fund etc.

The use elevation data in correcting indicator on access to drinking water is important when main source of the water comes from wells. Villages in higher altitude are relatively more difficult to get water from wells than villages in lower altitude since the water table depends on altitude of villages. The higher the altitude the lower the water table is. Boer et al. (2010) for example use correction factor of 0.50, 0.75 and 1.00 if elevation of the villages is low (<100 m a.s.l.), medium (100-500 m a.s.l.) and high (>500 m a.s.l.) respectively. This means that the sensitivity of villages to water scarcity will be higher in villages located in the higher altitude than those located in the lower altitude.

Table 4-14 Spider Graph showing relative condition of sensitivity, exposure, and adaptive capacity of districts according to their vulnerability profile

<table>
<tr><th>Vulnerability Profile</th><th>Spider Graph of Sensitivity and Exposure Indicators</th><th>Spider Graph of Adaptive Capacity Indicators</th></tr>
<tr><td>SEI Low – ACI High</td><td>
</td><td>
</td></tr>
<tr><td>SEI High – ACI High</td><td>
</td><td>
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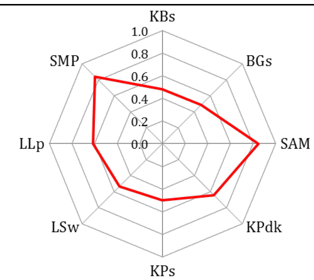
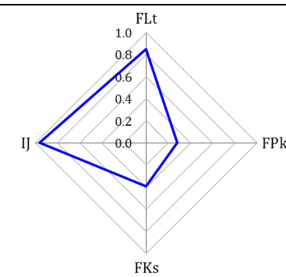
<tr><td>SEI Medium – ACI Medium</td><td>
</td><td>
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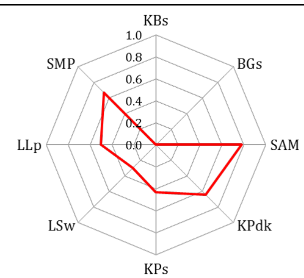
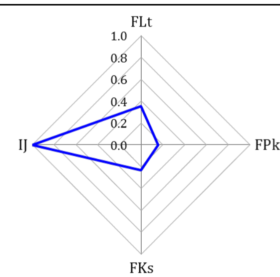
<tr><td>SEI Low – ACI Low</td><td>
</td><td>
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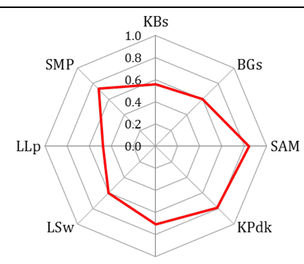
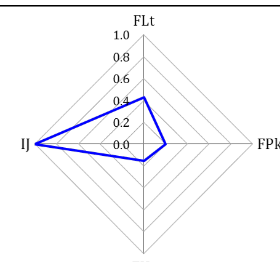
<tr><td>SEI High – ACI Low</td><td>
</td><td>
</td></tr>
</table>

The level of exposure of villages to flood can be also assessed based on their position in the river stream. Villages located in the downstream will have higher level of exposure the flood than those located in the upstream. Thus the use of number of HH/building near river side to define level of exposure of villages to flood without considering position of the villages may not properly reflect the level of sensitivity of the villages. Boer et al. (2010) proposed a method for defining flood exposure areas considering the position of the villages in the river stream as illustrated in Figure 4-12. It can be seen that the upper stream of the river is given notation number equal to 1 and it is called as 1st order river. The segment of the river that 1st order-rivers joint together is defined as the 2nd order-river. Then, the segment of the river that the 2nd order-rivers joint together is defined as the 3rd order-rivers etc. Thus following this rule, part of the river formed as a result of the confluence between a particular order-level is considered as the next level of river order. However, in the case where two orders with different levels meets at a particular segment, this can be referred to the highest level of the orders. In this example, the 4th order-river is the highest level. This highest order usually represents the location of the accumulation of surface flow, which very often becomes the target of flooding. The area with high level of flood exposure can be assumed as an area as far as 100 meters to the left and to the right sides of the highest order segment.

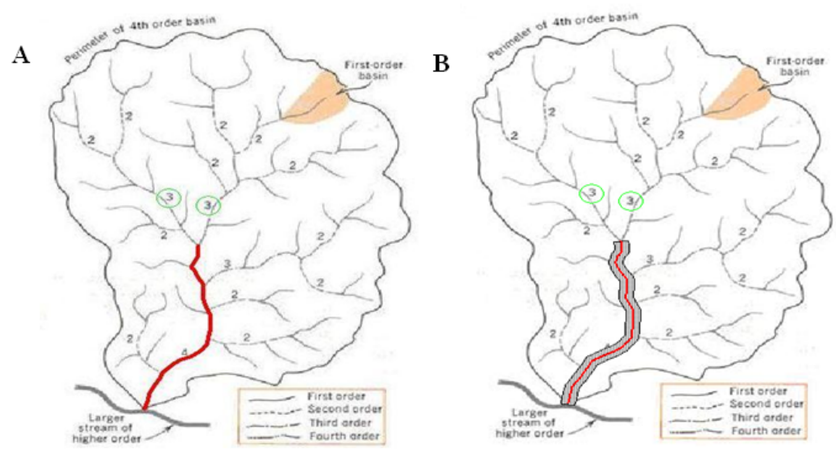


Figure 4-11 Determination of the highest order stream (A) & estimation of the water surge width (B)

4.4 Climate Risk Profile of Villages at CRB

As defined in Section 2.4, future climate risk in CRB is defined using the climate risk matrix (see Table 2-1). Climate change scenarios being used in this analysis are new IPCC scenarios, RCP-2.6, RCP-4.5, RCP-6.0, and RCP-8.5. The change in future probability of climate hazards is defined by comparing the probability of the climate hazards under current climate and under future climate (RC scenarios). Thus future probability of climate hazard would increase, remain the same or decrease.

4.4.1 Flood Risk in CRB

At current, level of flood risk of villages at CRB varied considerably from very low to very high (Figure 4-13). Majority of village falls under risk category of low (L) and low to medium (L-M). However under future climate if there is no change in level of vulnerability, the level of flood risk in most villages would increase irrespective of emission scenarios. The change in the level of flood risk is from L-M to M-H. The change is very significant, particularly for scenarios RCP4.5 and RCP8.5. In these two scenarios, the level of flood risk of most villages at CRB would increase in the future (Figure 4-14). It is also shown that the level of flood risk will continue to increase in the future. The level of flood risk for period 2071-2100 will be higher than those 2011-2040 and 2041-2070.

Among the four scenarios, RCP4.5 is the likely scenario that would happen in the future as this scenario is current pledge. Parties to the UNFCCC has already committed even though not legally binding to limit the emission following the scenario RCP4.5. Under this scenario, the flood risk of most of villages in the upper and lower part of CRB will increase. However the level of the risk of some villages in the middle part of CRB might decrease in the period 2011-2041, but it would increase again in the period 2041-2100 (Figure 4-14).

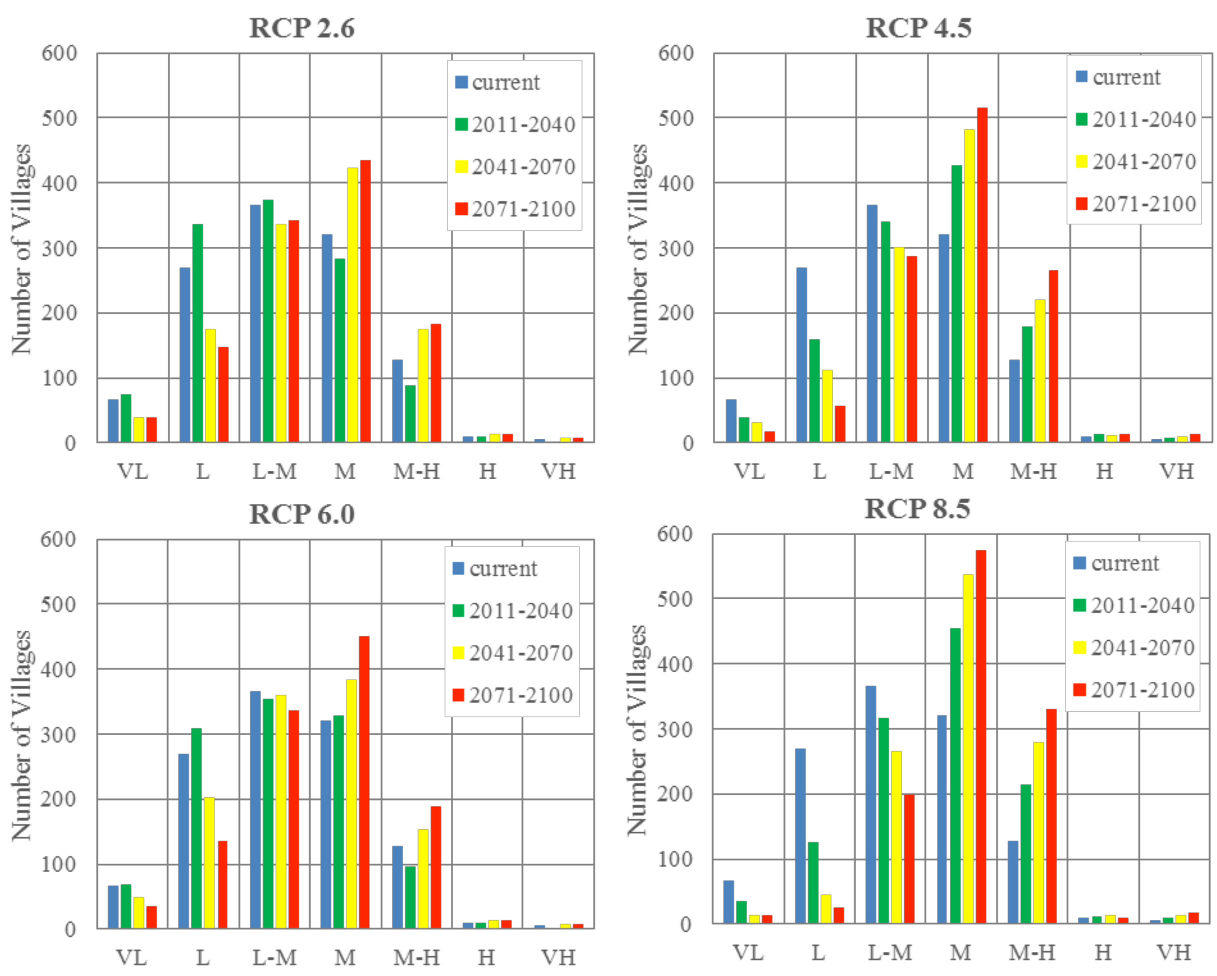


Figure 4-12 Number of villages based on level of flood risk under current and future climate

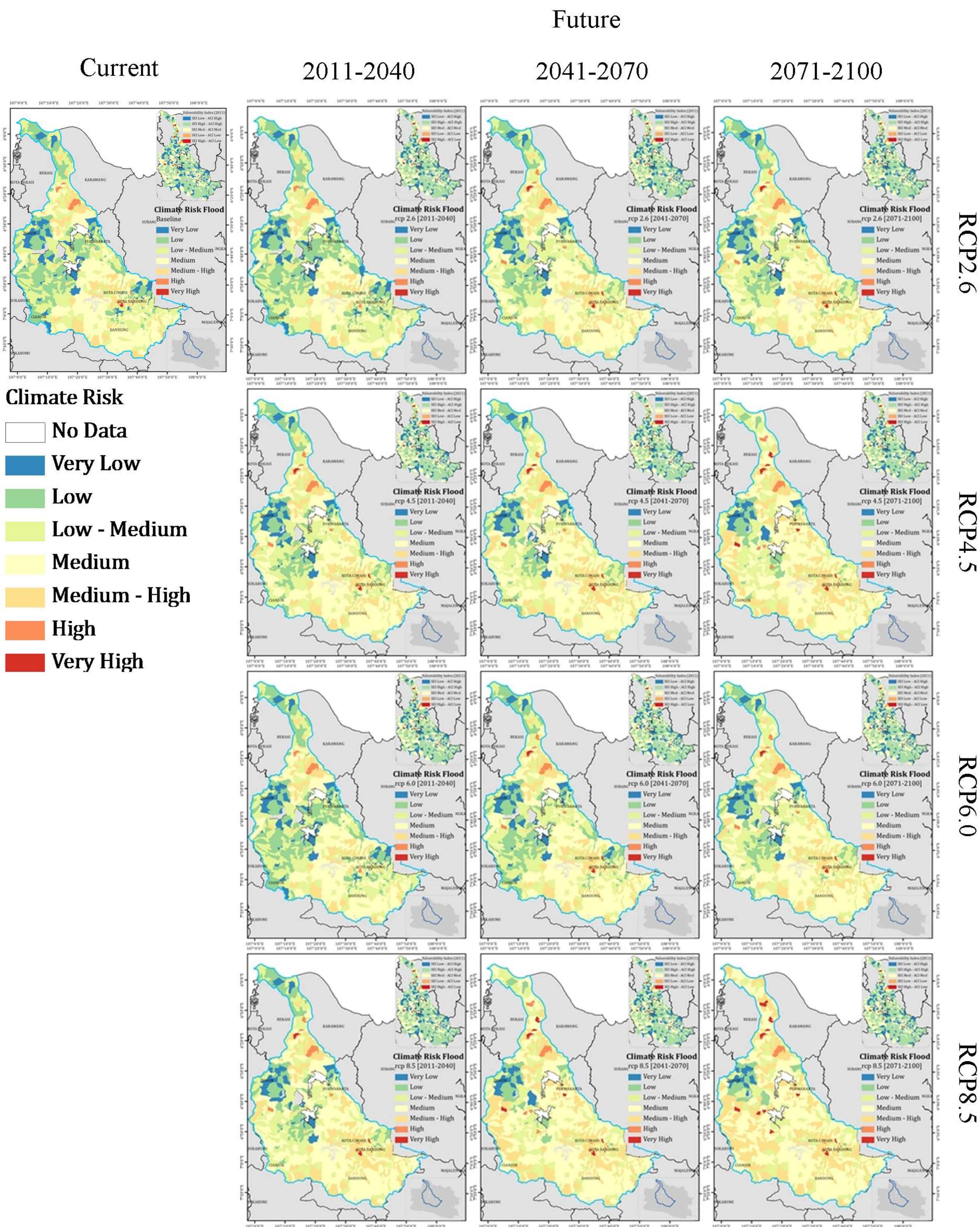


Figure 4-13 Flood Risk Level of Villages at CRB under current and future climate

4.4.2 Drought Risk in CRB

Drought risk of the villages in CRB under current climate is categorized mostly as medium (M). The drought risk would also increase in the future compare to present (Figure 4-15). In most cases, the drought risk would increase from medium (M) to Medium to High (M-H). The drought risks of most villages in CRB would increase in the future for all emission scenarios and the risk will continue to increase up to 2100 (Figure 4-16).

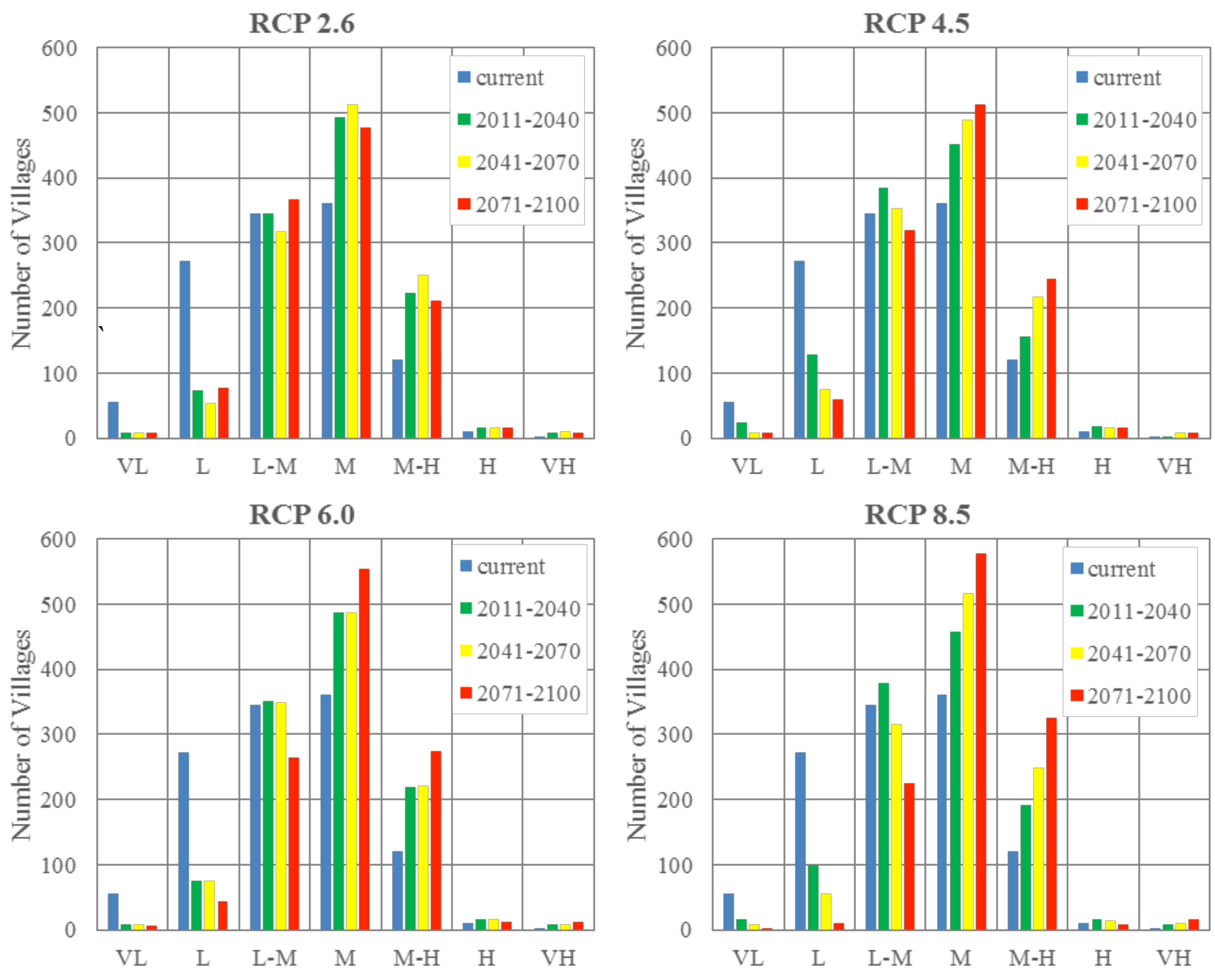


Figure 4-14 Number of villages based on level of drought risk under current and future climate

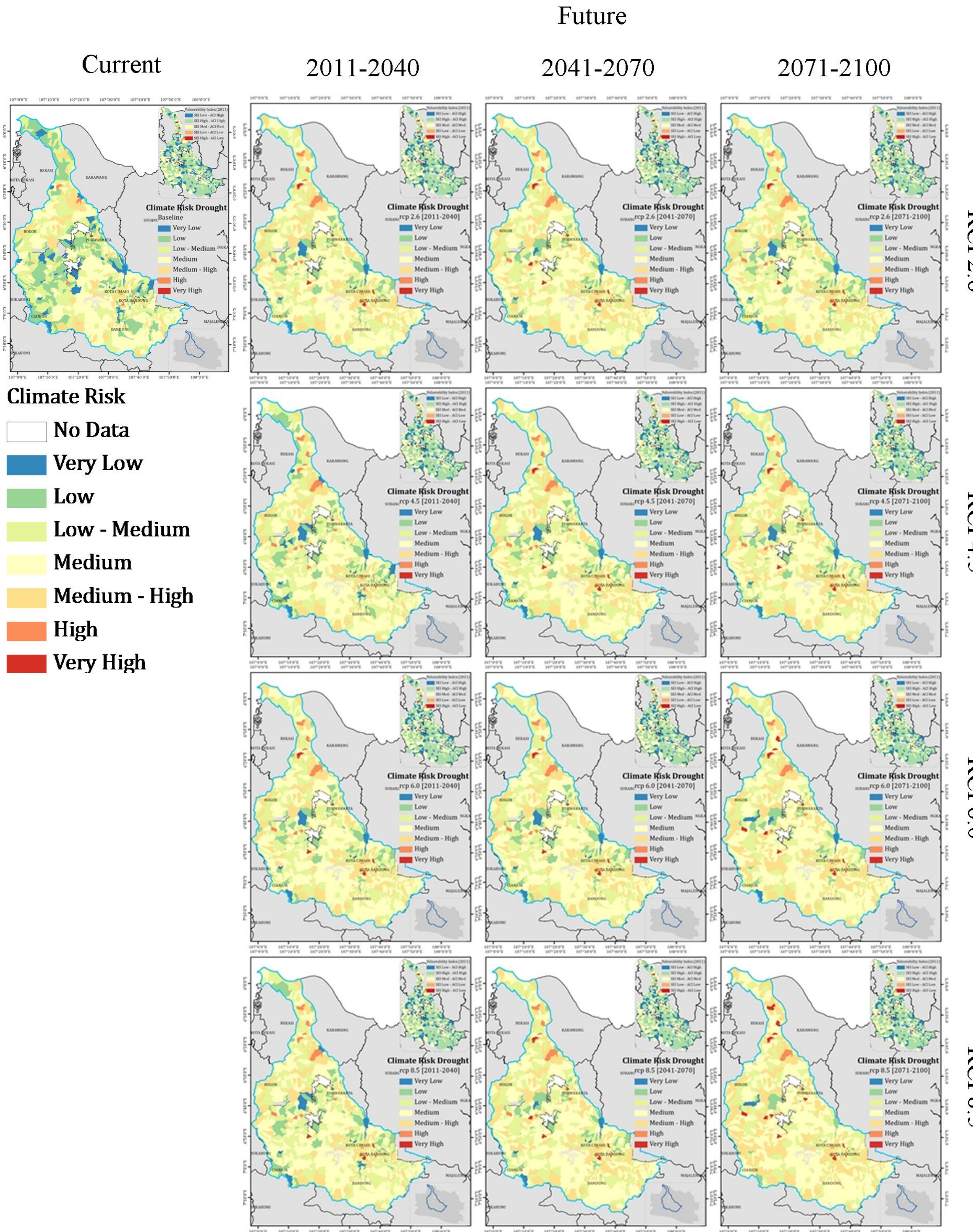


Figure 4-15 Drought Risk Level of villages at CRB under current and future climate

4.4.3 Priority Villages for the Implementation of Climate Change Adaptation

Most of villages in CRB at present already expose to climate risk. The risk mostly at medium level, however, if the implementation of development does not consider the villages vulnerability to potential impact of climate change, the level of climate risk would definitely increase. The implication of this, many of villages might become more vulnerable. Therefore, it is very important for local governments to plan and implement development program taking into account the result of the vulnerability and climate risk assessments. As previously mentioned, adaptation plans and actions should be targeted to reduce the vulnerability and the prioritized locations for the implementation of the actions should consider the climate risks.

Prioritization of locations for the implementation of adaptation actions should consider the level of climate risk. Prioritized locations are villages that at present already exposed to high climate risk and in the future they might expose to higher risk. Immediate adaptation actions should be done in these villages otherwise they would become more vulnerable in the future. Thus the urgency of adaptation actions will be determined by the level of climate risk not only at the present but also in the future. As the future risk is still uncertain, we can give more attention to the current climate risk and take into account the future risk in the process of prioritization. Table 4-15 presents the urgency of adaptation actions considering the current and future climate risks. Villages that need immediate adaptation actions to reduce their vulnerability are presented in Table 4-16.

Table 4-15 Urgency of climate change adaptation actions based on on the level of current and future climate risk

Urgency of Adaptation	Current climate risk	Future Climate Risk	Notes	Number of villages
Immediate action (1-5 years)	M-H, H, VH	M-H, H, VH	Climate risk at present is between Medium to High, High or Very High and in the future it may remain Medium to High or increase to High or to Very High or remains High or Very High	21 (Flood) 21 (Drought)
Short-term (5-10 years)	M	M-H, H	Climate risk at present is Medium and in the future it will increase to Medium to High or to High or to Very High	123 (Flood) 112 (Drought)
Medium Term (10-20 years)	M	M	Climate risk at present is Medium and in the future remain medium	321 (Flood) 360 (Drought)
Long Term (10-25 years)	L-M	L-M, M, M-H	Climate risk at present is Medium in the future it remains Medium or increases to Medium to High or to High or to very high	366 (Flood) 346 (Drought)
Very Long-Term (>25 years)	VL, L	VL, L, L-M, M	Climate risk at present is between Low and Low to Medium and in the future it remains Low to Medium or increases to Medium, or to Medium to High, or to High or to Very High	336 (Flood) 328 (Drought)

Table 4-16 shows that there are 25 villages required immediate adaptation actions. All these villages already exposed to both flood and drought risk, except for Hegarmanah, Cinangsi, Gudang, and Karangsegar which exposed only to high drought risk and Cirangrang, Cigondewah Kaler, Gempol Sari and Jamika only to high flood risk. There are quite large numbers of villages that need short term adaptation actions (see Table 4-15), in which current level of climate risk are still medium (M), but in the future the risk will increase to M-H or High.

Table 4-16 List of villages which needs to received immediate adaptation programs/actions

District	Sub District	Villages	Flood		Drought	
			Current	Future	Current	Future
Cianjur	Bojongpicung	Hegarmanah	-	-	H	H
	Cikalongkulon	Cinangsi	-	-	M-H	H
		Gudang	-	-	M-H	H
	Sukaresmi	Ciwalen	M-H	H	M-H	H
Purwakarta	Sukatani	Cibodas	M-H	H	M-H	H
Karawang	Ciampel	Kutamekar	H	H	H	H
		Parungmulya	H	H	M-H	H
	Klari	Cibalongsari	VH	VH	VH	VH
Bekasi	Cikarang Timur	Cipayung	H	VH	H	H
	Kedungwaringin	Bojongsari	H	H	M-H	H
	Pebayuran	Bantarjaya	M-H	H	M-H	H
		Karangsegar	-	-	M-H	H
Bandung City	Babakan Ciparay	Babakan Ciparay	VH	VH	H	H
		Cirangrang	M-H	H	-	-
		Margahayu Utara	VH	VH	H	H
		Margasuka	VH	VH	H	H
	Bandung Kulon	Cigondewah Kaler	H	H	-	-
		Gempol Sari	H	H	-	-
	Batununggal	Binong	VH	VH	VH	VH
		Cibangkong	H	H	M-H	H
		Kebon Waru	H	H	H	H
	Bojongloa Kaler	Babakan Asih	VH	VH	H	VH
		Jamika	H	H	-	-
	Cibeunying Kaler	Cigadung	H	VH	H	H
	Cicendo	Sukaraja	M-H	H	H	H

5 CONCLUSIONS

In period 2005-2011, the level of exposure and sensitivity of most villages in CRB has increased from medium to high, but the adaptive capacity also increased from medium to high. Main factor causing the increase in sensitivity is access to clean water and that causing the increase in adaptive capacity is the improvement of access to electricity.

There are about 17 very vulnerable villages in CRB in 2011. Most of them locate in Bandung City (7 villages), namely Babakan Ciparay, Cirangrang, Margahayu Utara, Margasuka, Binong, Babakan Asih and Cigadung and some others are in Purwakarta, Karawang, Cianjur and Bekasi Districts.

The vulnerability index can be used as a tool to monitor and to measure the impact of adaptation actions. To improve the effectiveness of this index in evaluating the impact of adaptation actions in increasing the resilience of the villages to climate change impact, the analysis should use more biophysical and socio-economic indicators representing level of exposure, sensitivity and adaptive capacity of the village whenever available. The use of GIS in generating the indicators for representing level of exposure is recommended to increase the accuracy.

With assumption no change in vulnerability index of villages in CRB in the future, level of climate risk of most villages in CRB will increase in the future. There are 25 villages in CRB now having medium to very high level of climate risk and in the future the level of risk would remain or increase to high and very high. Most of these villages are already exposed to both high flood and drought risk. These villages should be targeted for the implementation of immediate adaptation actions.

More than 100 villages should be prioritized for the implementation of short-term adaptation programs. The current level of climate risk in these villages are still medium (M), but in the future the risk will increase to M-H or High.

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