Department of Science and Technology (DOST)

Impacts of land use change and an integrated assessment of vulnerability to flooding:

The case of Sta. Rosa-Silang subwatershed

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- Flooding in Study Site
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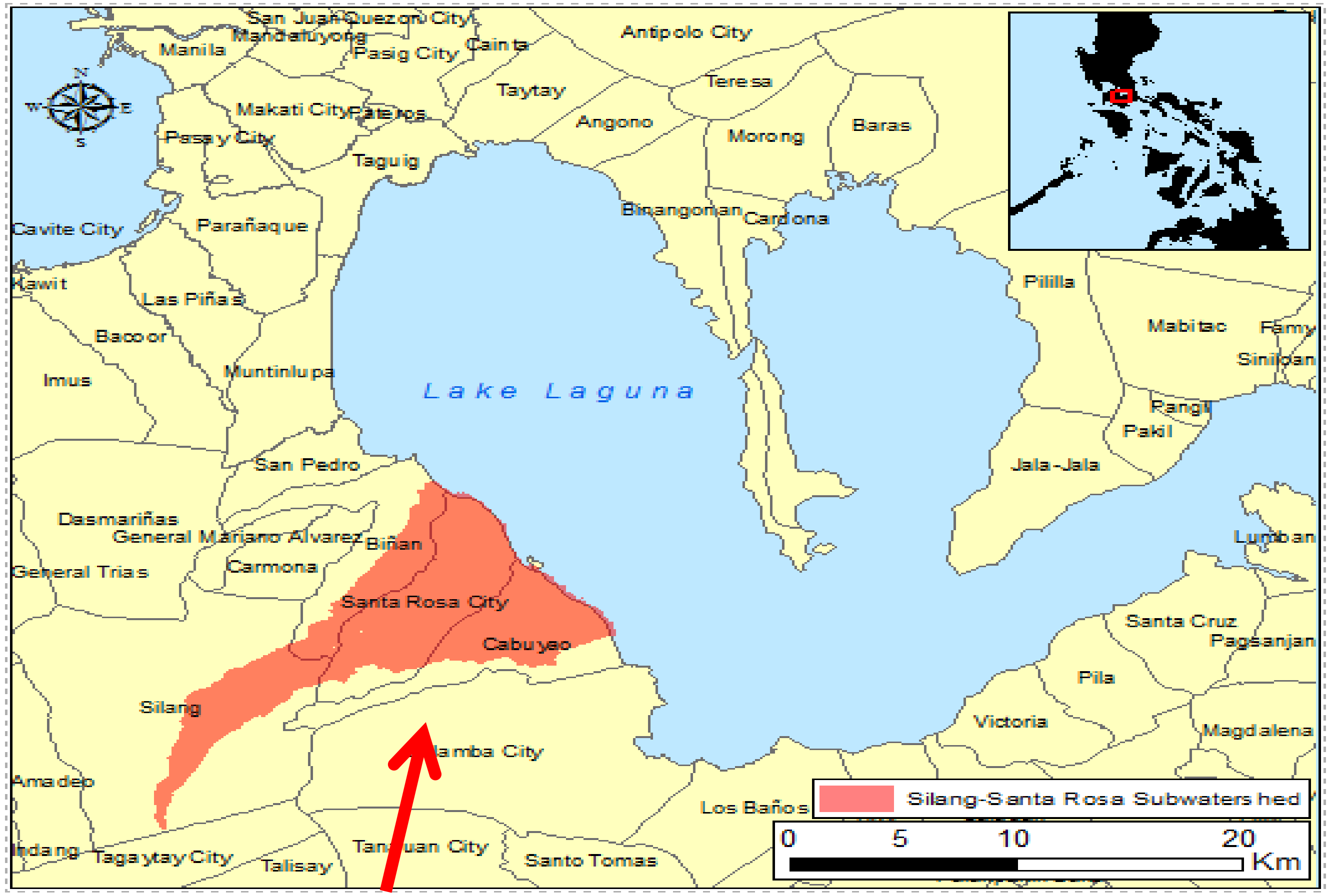
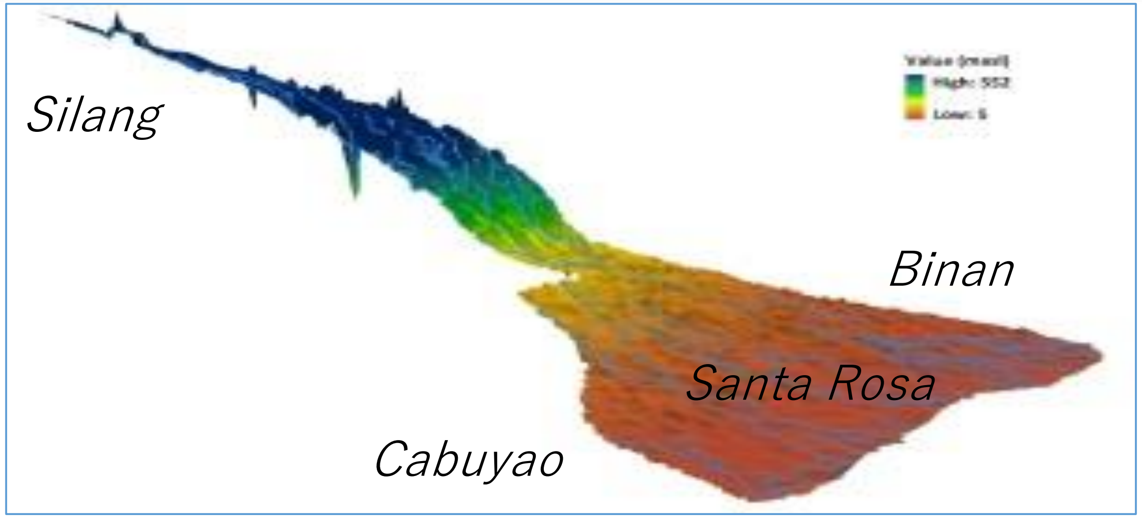
INTRODUCTION



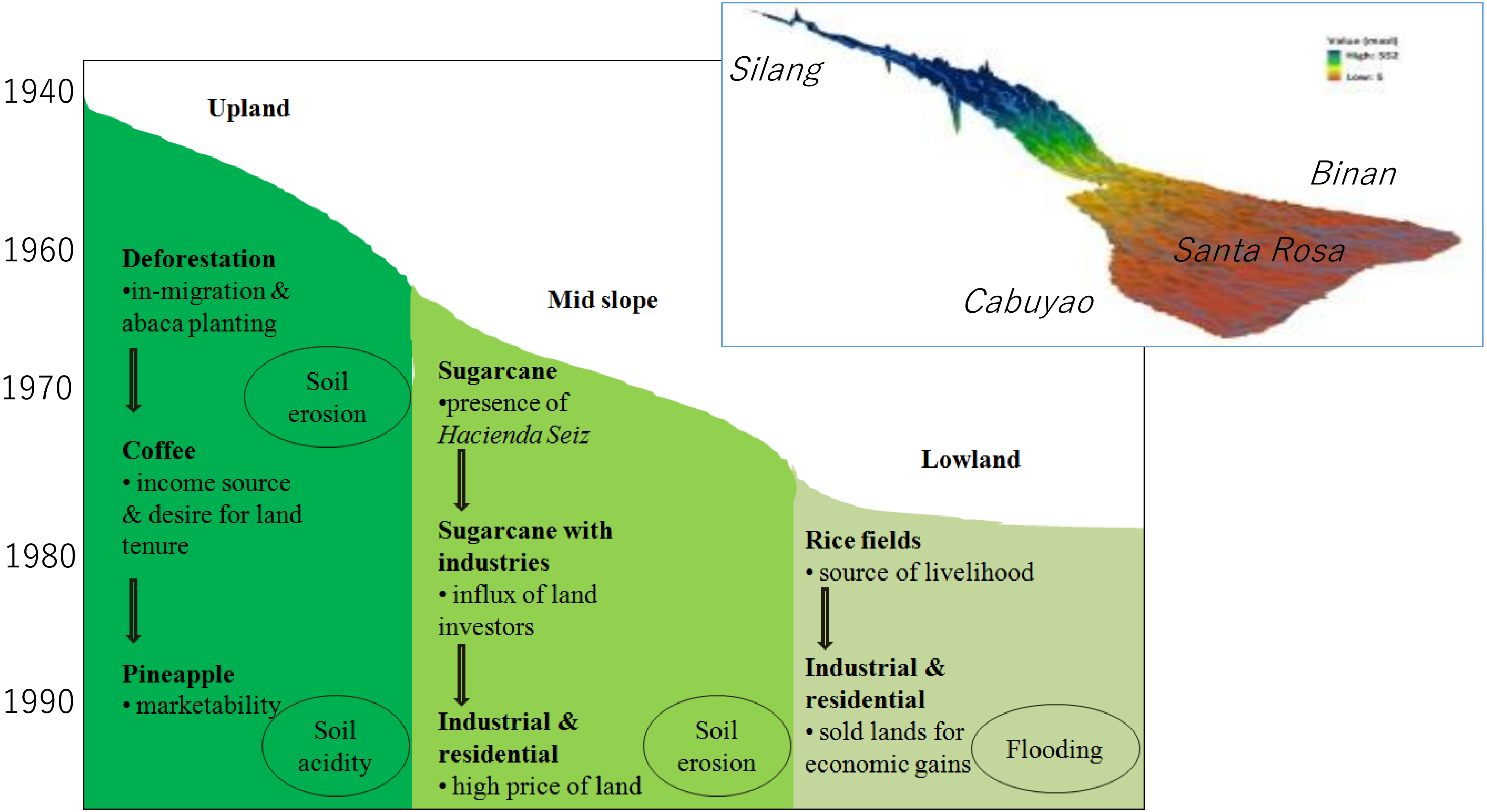


Silang-Santa Rosa Subwatershed, Philippines

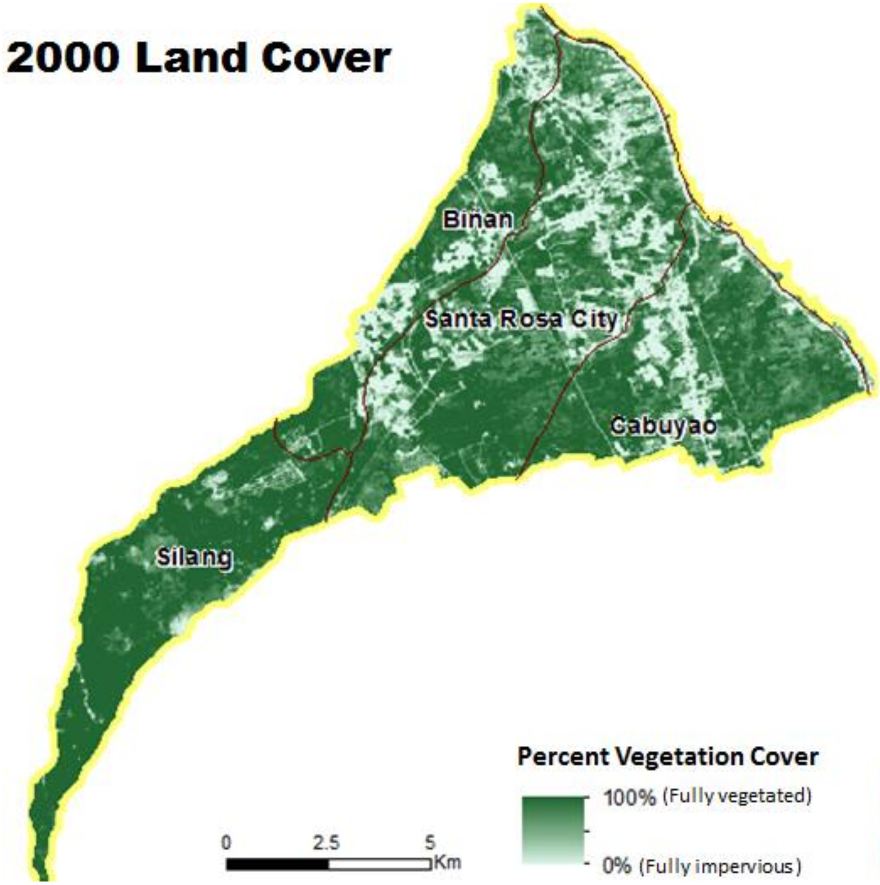
Area shaded in red (above), topography (right)

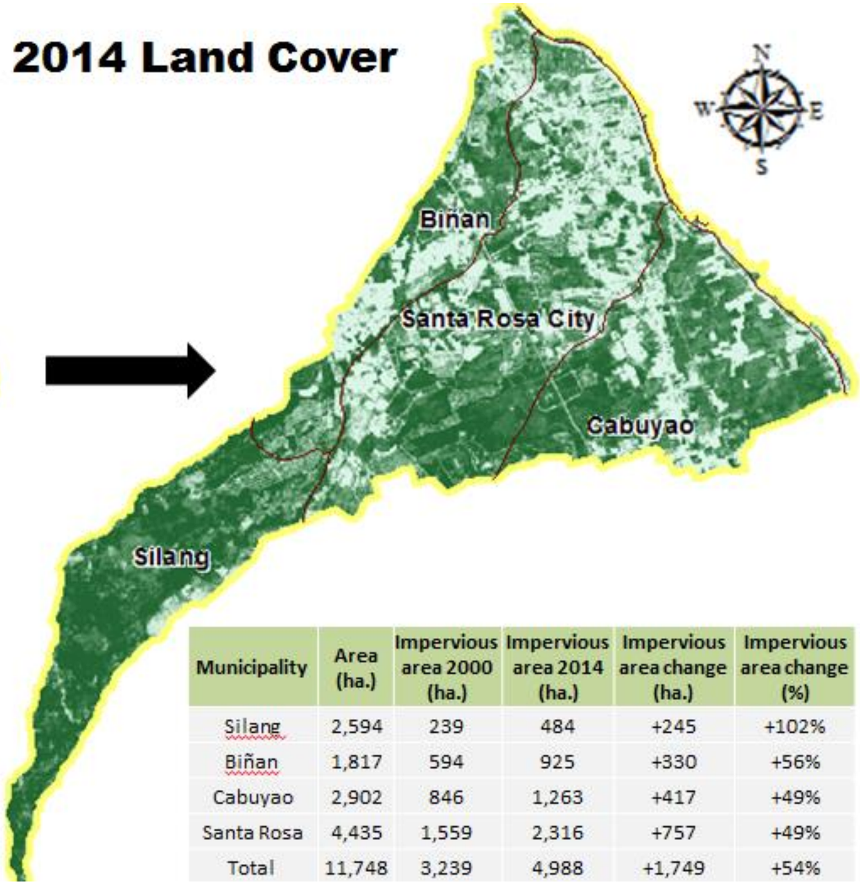
- Multiple cities in 120 km^2
- Rapid economic growth
- Population growth and migration (570,000 people)
- Massive land use changes in past 2 decades
- Flooding, environmental degradation, pollution, waste

LAND COVER CHANGES



Rapid conversion of vegetated areas to built-up land





Municipality	Area (ha.)	Impervious area 2000 (ha.)	Impervious area 2014 (ha.)	Impervious area change (ha.)	Impervious area change (%)
Silang	2,594	239	484	+245	+102%
Biñan	1,817	594	925	+330	+56%
Cabuyao	2,902	846	1,263	+417	+49%
Santa Rosa	4,435	1,559	2,316	+757	+49%
Total	11,748	3,239	4,988	+1,749	+54%

- Impervious area of sub-watershed increased by 54% (from 3,239 ha. to 4,988 ha.).
- Vegetated area decreased by 21% (from 8,509 ha. to 6,760 ha).
- Upstream: Impervious area increased by 102% in upstream municipality of Silang, and also increased in upstream parts of Biñan and Santa Rosa City, causing higher runoff (more frequent and intense floods downstream).
- Downstream: The most flood-prone areas in the watershed underwent some of the most development.

Land Conversion in the Downstream Area

Year **2007 & 2014** Orthophotos in the downstream barangays of Sta. Rosa experiencing Land conversion from **Rice fields** to **Subdivisions**

Weather-related disasters: Flooding

Santa Rosa
Philippines
Sep. 2006
with Typhoon Milenyo

(Photos: E. C. Creencia)

OBJECTIVES

I. Hydrologic Modeling

The study generally aimed **to:**

- Assess the landslide and flooding high risk areas along the Santa Rosa-Silang Subwatershed using the SWAT, HEC-HMS and HEC-RAS hydrological models.

Specifically, it intended to:

a) **Predict runoff and sediment yield** in the site using SWAT model from the spatial and climatic inputs

b) **Identify high risk areas** along the site vulnerable to landslides and flooding

VULNERABILITY

- A function of the **EXPOSURE** (who or what is at risk) and the **SENSITIVITY OF THE SYSTEM** (the degree to which people and places can be harmed)
- Vulnerability arises from the intersection of **human systems**, the **built environment**, and the **natural environment**
- The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards (UN/ISDR, Geneva 2004)
- Extent to which climate change may damage or harm a system. It depends on system's sensitivity and ability to adapt to new climatic conditions

OBJECTIVES

II. Vulnerability assessment

The study generally aimed to**:**

- Survey 3 coastal communities (Sinalhan, Aplala, Caingin) with respect to their exposure, sensitivity, impacts and capability to adapt to floods.

Specifically, it intended to:

a) Determine the reasons why the three barangays are vulnerable to flood;
b) Determine the experiences, observations, and coping mechanisms of the residents in the three barangays during floods and extreme weather conditions;
c) Find out views of the residents of the three barangays on government intervention and implementation of policies during floods and extreme weather conditions;
d) Assess the vulnerability of these communities to flooding using the data gathered; and
e) Recommend appropriate adaptation and mitigation strategies to residents and local government officials of Santa Rosa City.

METHODOLOGY

I. Hydrologic Modeling

- **Soil and Water Assessment Tool**

A physically-based, river basin-scale, continuous event model developed to quantify the water, sediment, and agricultural nutrient yields of large watersheds.

The model bears its simulations on the area's soil types, slope, and land management conditions.

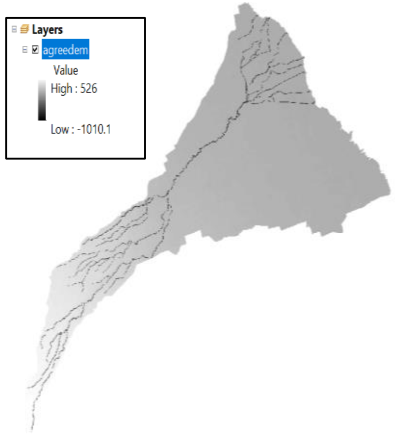
SWAT can quantify:

- ✓ **potential flood volume**
- ✓ **potential erosion and sediment accumulation**

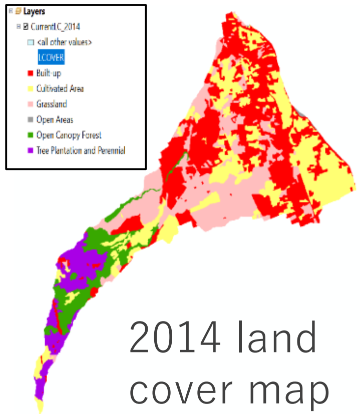
METHODOLOGY

Preparation of SWAT Model Inputs:

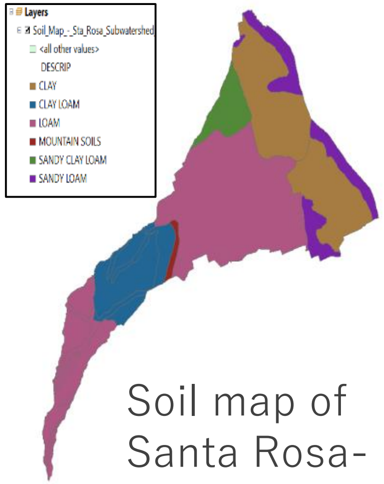
- Geographical data of the Santa Rosa-Silang Subwatershed
  - a) Digital terrain model (DTM)
  - b) 2014 land use map
  - c) Soil map
- Historical climatic data from 1980 to 2015
  - a) Daily rainfall
  - b) Daily maximum and minimum temperatures



Reconditioned digital terrain map (DTM) of Santa Rosa-Silang Subwatershed



2014 land cover map of Santa Rosa-Silang Subwatershed



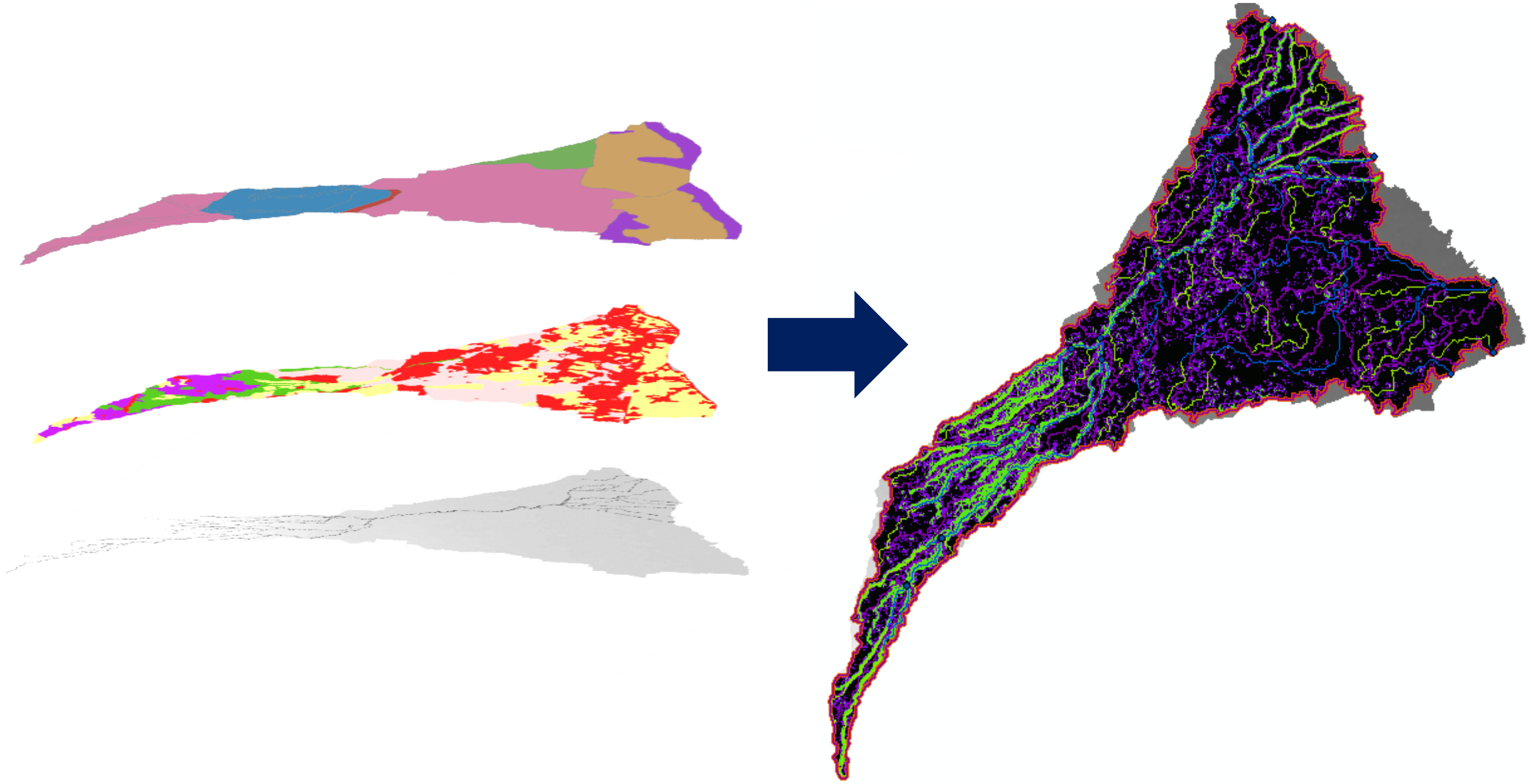
Soil map of Santa Rosa-Silang Subwatershed

- The 36-year (1980 to 2015) climatic data was converted and compiled to a particular format (.txt) required by the SWAT model.

METHODOLOGY

Development of SWAT Model:

- The DTM map was entered in the model's platform.
- Streams and outlets were created based on the changes in elevation along the area.



FLOOD MODELLING

ArcGIS10

HEC-HMS

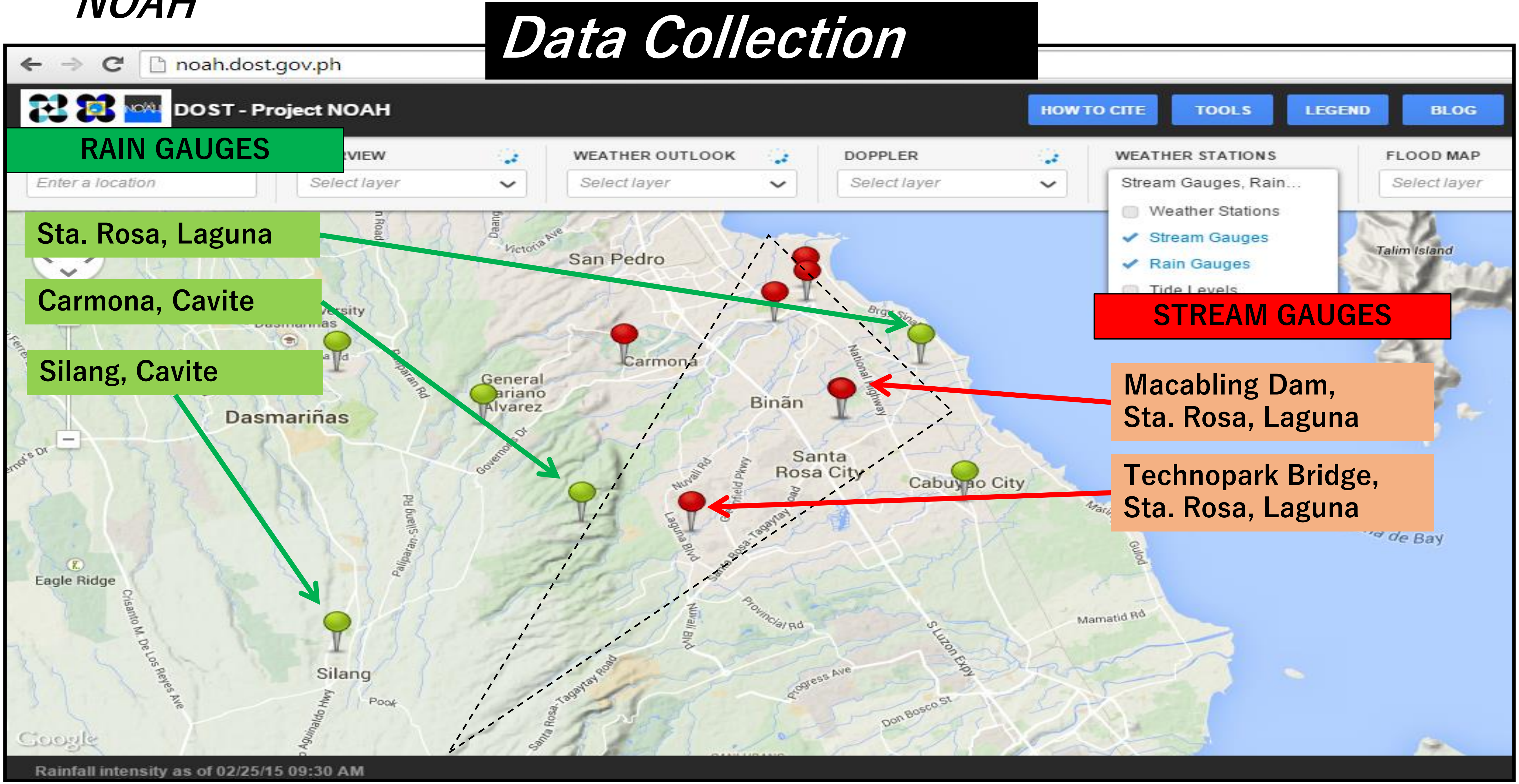
Hydrologic Engineering Center – Hydrologic Modeling System

HEC-RAS

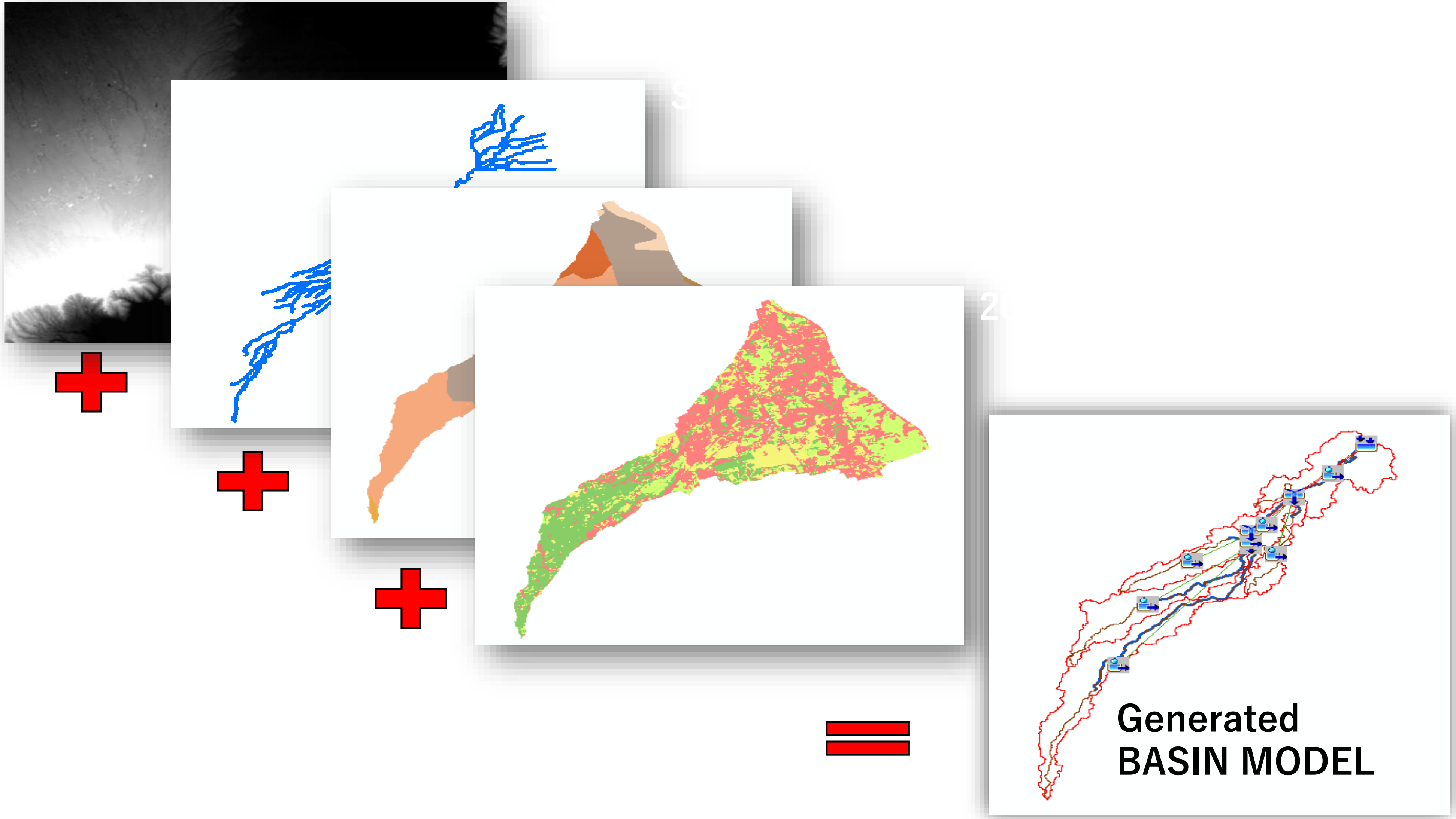
Hydrologic Engineering Center – River Analysis System

Collection of precipitation and discharge data from DOST-Project NOAH

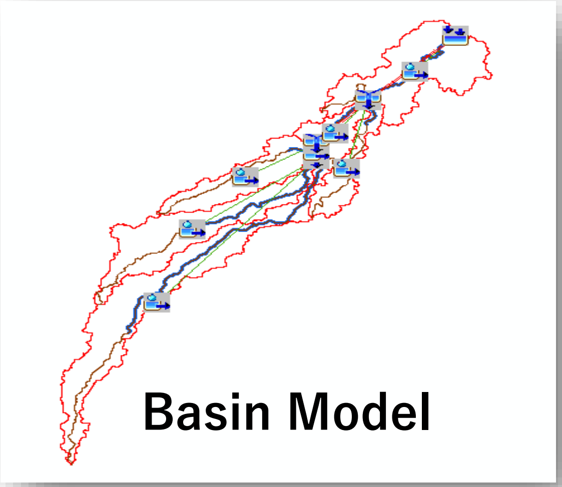
Data Collection

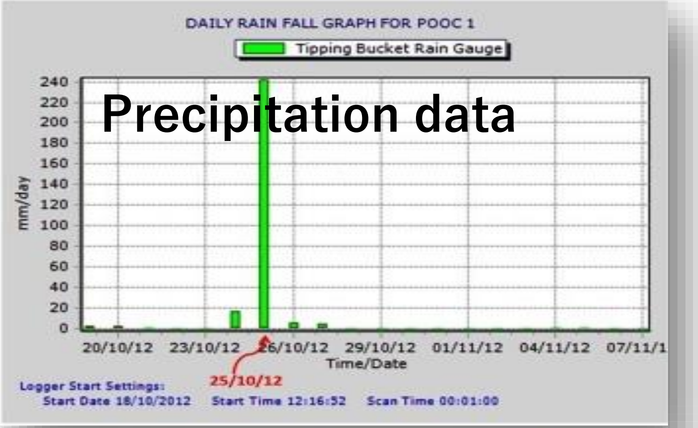


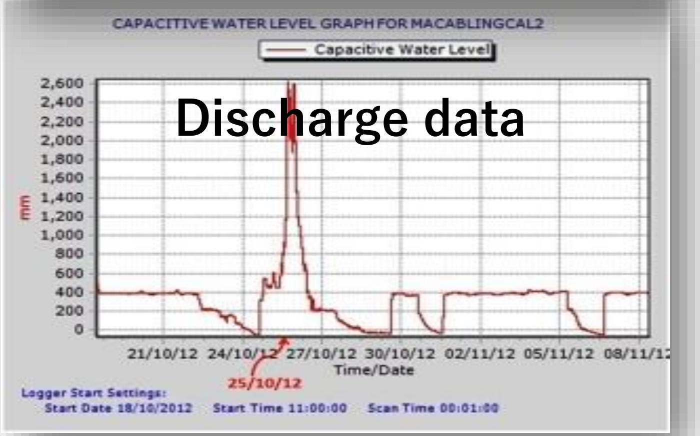
Generation of Basin Model using ArcGIS10 with HEC-GeoHMS and HEC-GeoRAS extensions

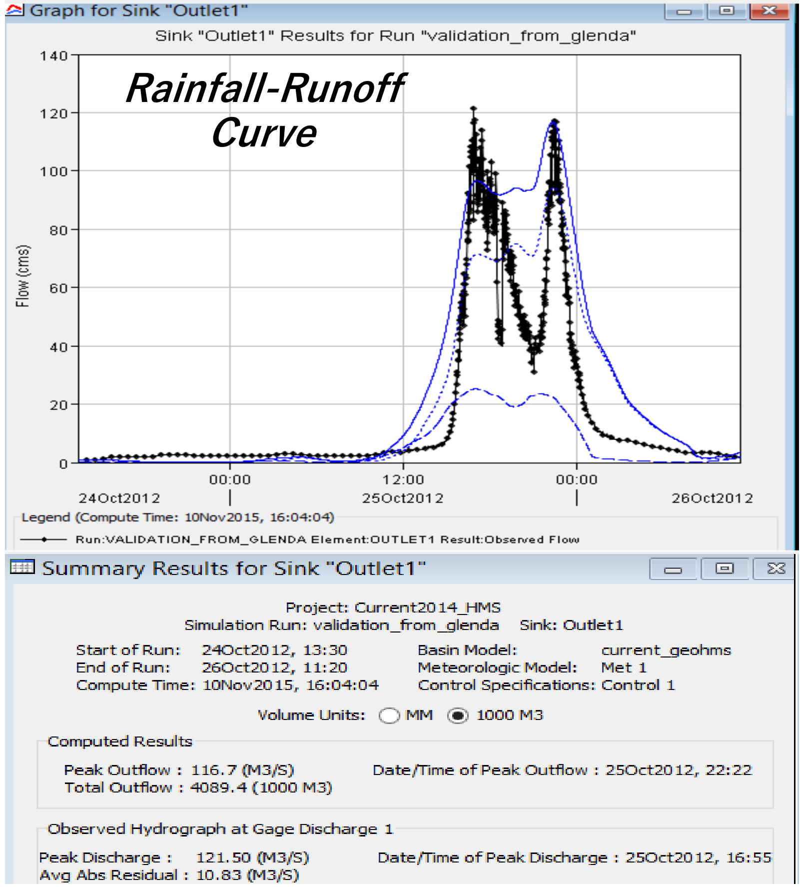


HEC-HMS

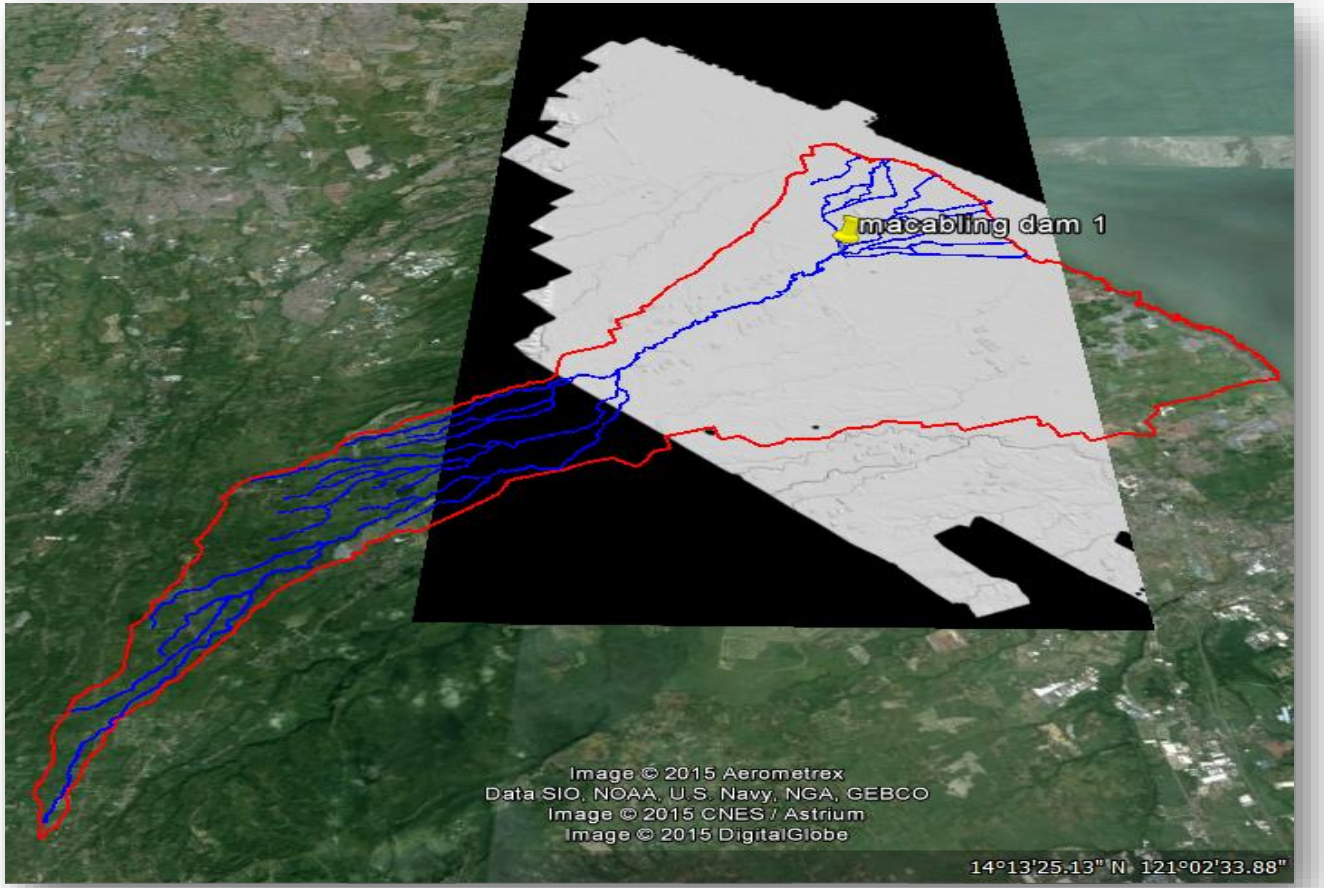

Basin Model

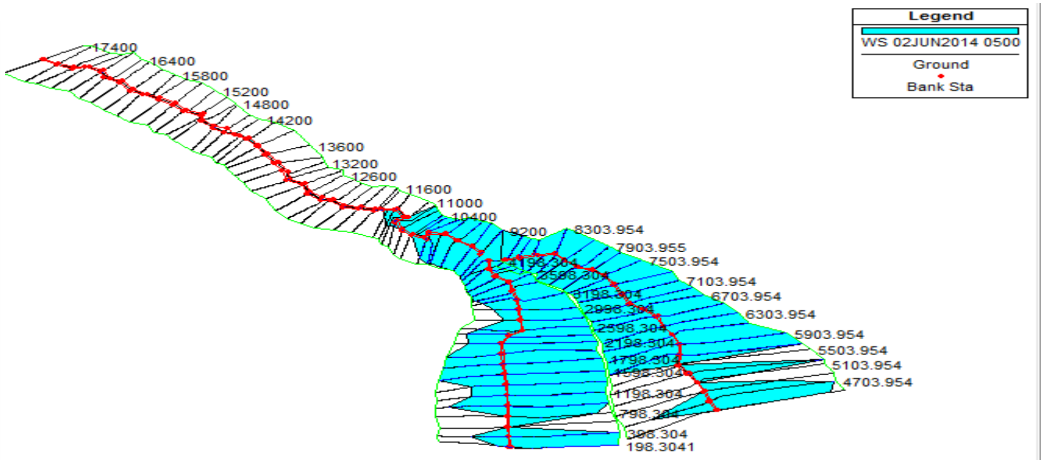

DAILY RAIN FALL GRAPH FOR POOC 1
Tipping Bucket Rain Gauge
Precipitation data
mm/day
20/10/12 23/10/12 26/10/12 29/10/12 01/11/12 04/11/12 07/11/1
Time/Date
25/10/12
Logger Start Settings:
Start Date 18/10/2012 Start Time 12:16:52 Scan Time 00:01:00

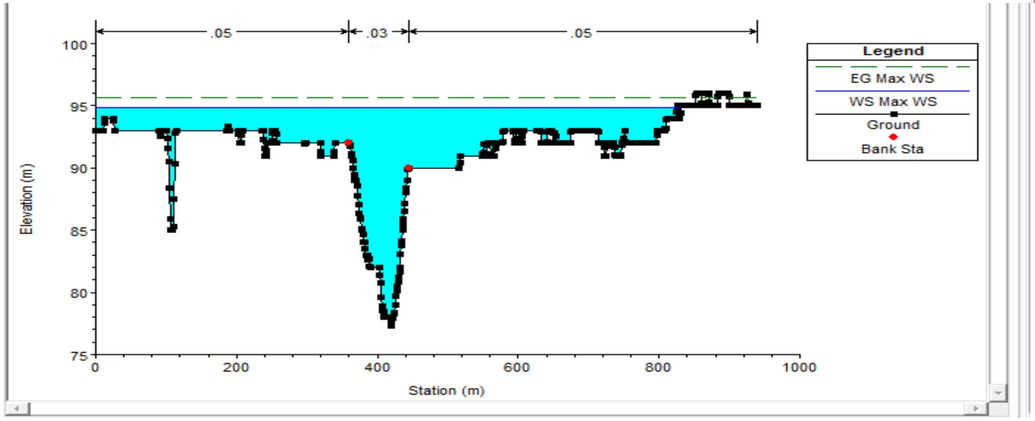

CAPACITIVE WATER LEVEL GRAPH FOR MACABLINGCAL2
Capacitive Water Level
Discharge data
mm
21/10/12 24/10/12 27/10/12 30/10/12 02/11/12 05/11/12 08/11/12
Time/Date
25/10/12
Logger Start Settings:
Start Date 18/10/2012 Start Time 11:00:00 Scan Time 00:01:00


Graph for Sink "Outlet1"
Sink "Outlet1" Results for Run "validation_from_glenda"
Rainfall-Runoff Curve
Flow (cms)
24Oct2012 25Oct2012 26Oct2012
Legend (Compute Time: 10Nov2015, 16:04:04)
Run:VALIDATION_FROM_GLENDA Element:OUTLET1 Result:Observed Flow
Summary Results for Sink "Outlet1"
Project: Current2014_HMS
Simulation Run: validation_from_glenda Sink: Outlet1
Start of Run: 24Oct2012, 13:30
End of Run: 26Oct2012, 11:20
Compute Time: 10Nov2015, 16:04:04
Basin Model: current_geohms
Meteorologic Model: Met 1
Control Specifications: Control 1
Volume Units: MM 1000 M3
Computed Results
Peak Outflow : 116.7 (M3/S)
Total Outflow : 4089.4 (1000 M3)
Date/Time of Peak Outflow : 25Oct2012, 22:22
Observed Hydrograph at Gage Discharge 1
Peak Discharge : 121.50 (M3/S)
Avg Abs Residual : 10.83 (M3/S)
Date/Time of Peak Discharge : 25Oct2012, 16:55

HEC-RAS


macabling dam 1
Image © 2015 Aerometrex
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2015 CNES / Astrium
Image © 2015 DigitalGlobe
14°13'25.13" N 121°02'33.88"


Legend
WS 02JUN2014 0500
Ground
Bank Sta
17400
16400
15800
15200
14800
14200
13600
13200
12600
11600
11000
10400
9200
8303.954
7903.955
7503.954
7103.954
6703.954
6303.954
5903.954
5503.954
5103.954
4703.954
1198.304
798.304
398.304
198.3041

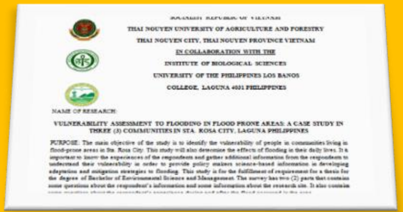

.05
.03
.05
Legend
EG Max WS
WS Max WS
Ground
Bank Sta
Elevation (m)
100
95
90
85
80
75
0
200
400
600
800
1000
Station (m)

METHODOLOGY

II. Vulnerability Assessment

HOUSEHOLD SURVEY

- Purposive Sampling Method
- 50 households per barangay (150 overall)


THAI NGUYEN UNIVERSITY OF AGRICULTURE AND FORESTRY
THAI NGUYEN CITY, THAI NGUYEN PROVINCE VIETNAM
IN COLLABORATION WITH THE
INSTITUTE OF BIOLOGICAL SCIENCES
UNIVERSITY OF THE PHILIPPINES LOS BANOS
COLLEGE, LAGUNA 4031 PHILIPPINES

NAME OF RESEARCH:

VULNERABILITY ASSESSMENT TO FLOODING IN FLOOD PRONE AREAS: A CASE STUDY IN THREE (3) COMMUNITIES IN STA. ROSA CITY, LAGUNA PHILIPPINES

PURPOSE: The main objective of the study is to identify the vulnerability of people in communities living in flood-prone areas in Sta. Rosa City. This study will also determine the effects of flooding in their daily lives. It is important to know the experiences of the respondents and gather additional information from the respondents to understand their vulnerability in order to provide policy makers science-based information in developing adaptation and mitigation strategies to flooding. This study is for the fulfillment of requirement for a thesis for the degree of Bachelor of Environmental Science and Management. The survey has two (2) parts that contains some questions about the respondent's information and some information about the research site. It also contains

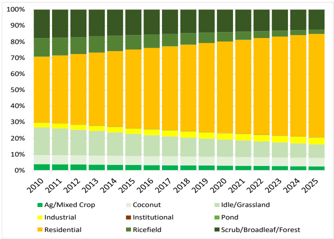
KEY INFORMANT SURVEY

- City official based on expertise
  - ✓ CPDO
  - ✓ Local Building Office
  - ✓ City Veterinarian Office
  - ✓ CDRRMO
- One official in each barangay

DATA ANALYSIS

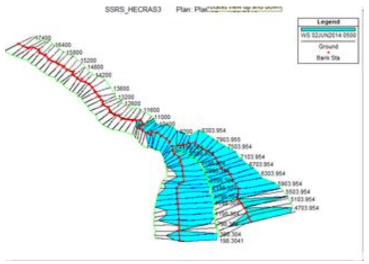
- Descriptive Statistics
- Two-way ANOVA without replication
- Socio-economic vulnerability scoring matrix and classification

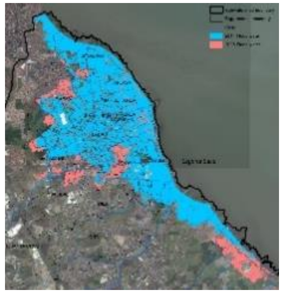
III. Participatory Watershed Land-use Management



- Participatory approach
- Land-use change model
- GIS / remote sensing

Step 1: Scenario development





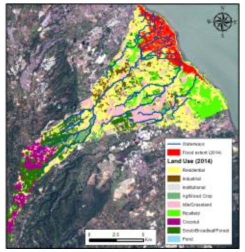
- Hydrological model
- Downscaling

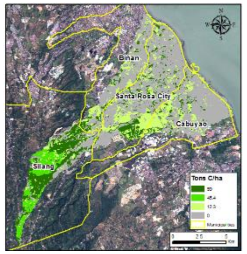
Step 2: Risk assessment

Step 3: Climate change measure development

- Expert meeting
- Stakeholder consultation

Step 4: Climate-sensitive land-use planning





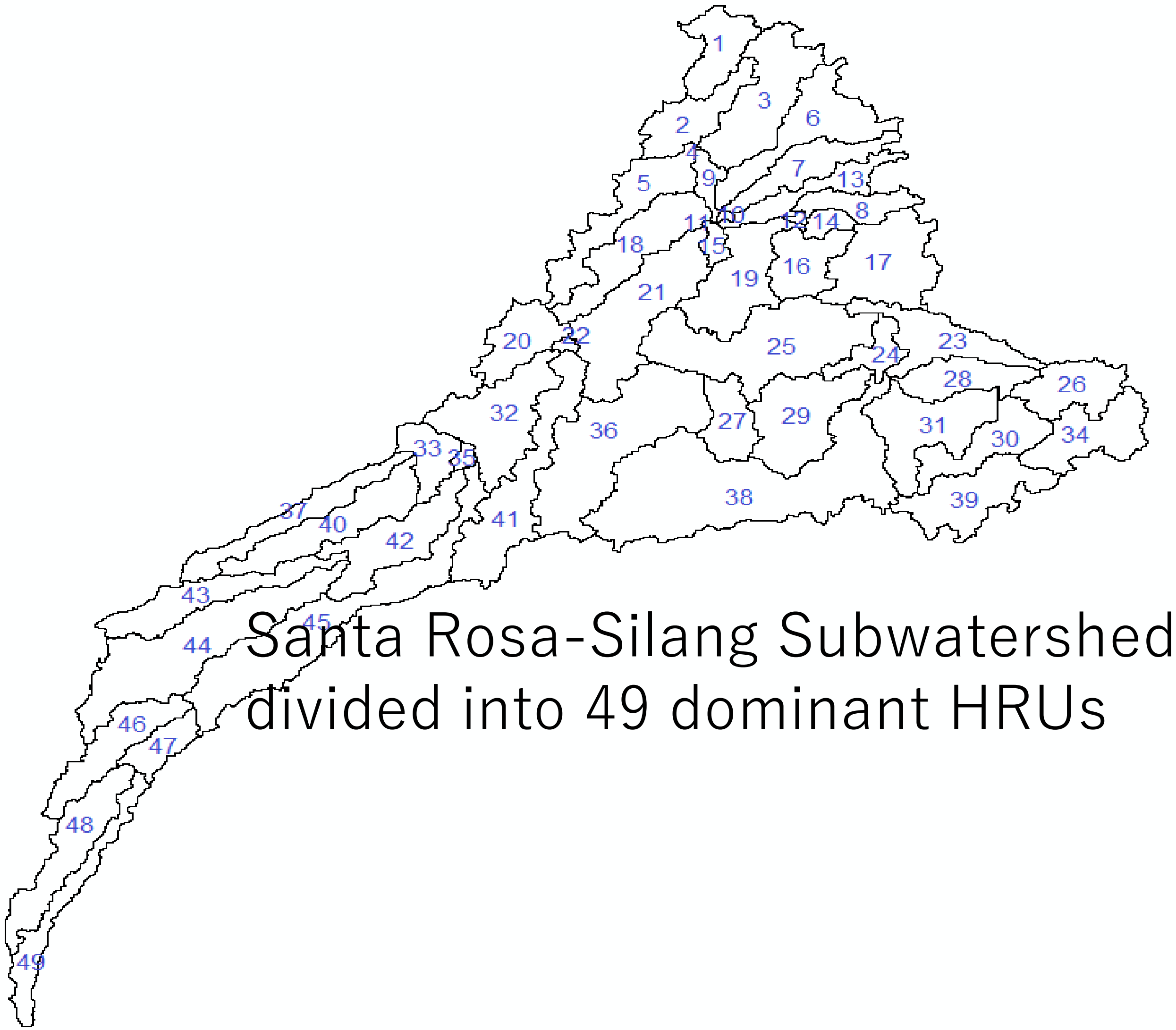
- Land-use plan
- Development plan
- Climate change plan

Results from SWAT Modeling

Simulated surface flow and sediment yield volumes of the dominant 49 HRUs.

HRU #	Flow (cms)	Sediment (tons)
1	0.7158	135827.48
2	0.7917	156458.84
3	1.4540	306038.93
4	2.2454	462669.14
5	1.1697	11936.78
6	1.2591	260517.12
7	0.8869	67671.98
8	28.4869	69203.81
9	3.6181	39202.20
10	2.1672	331528.82
11	0.0015	133.20
12	3.5459	225821.76
13	24.5071	119784.40
14	2.2783	213405.49
15	18.1310	31770.96
16	0.7298	7577.32
17	1.3643	174439.18
18	1.2397	9327.67
19	1.2392	220181.69
20	0.6391	12474.23
21	16.7404	178221.34
22	14.0753	36637.67
23	11.9047	10481.01
24	5.7938	44970.18
25	5.1448	45267.61

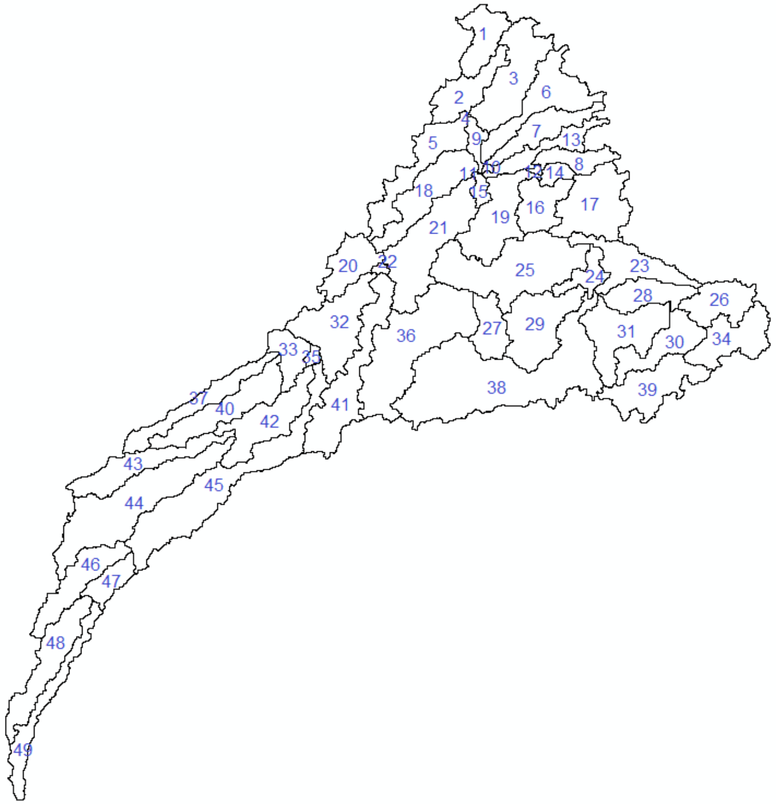
HRU #	Flow (cms)	Sediment (tons)
26	15.4768	7254.95
27	0.6312	5373.93
28	2.8183	21510.92
29	1.3804	8717.31
30	0.8273	4499.94
31	1.3195	13773.01
32	12.6095	275702.37
33	2.0898	812253.07
34	0.9560	3622.33
35	9.0903	18126.48
36	2.1310	29016.74
37	0.6794	304539.79
38	4.0297	32729.82
39	1.2247	3419.03
40	0.9388	423946.48
41	1.4265	20908.88
42	3.9457	478249.34
43	0.8058	5683.19
44	2.2595	448262.72
45	5.0766	26058.86
46	0.8655	10281.51
47	2.3273	382872.65
48	1.1236	225854.33
49	0.8055	152628.49

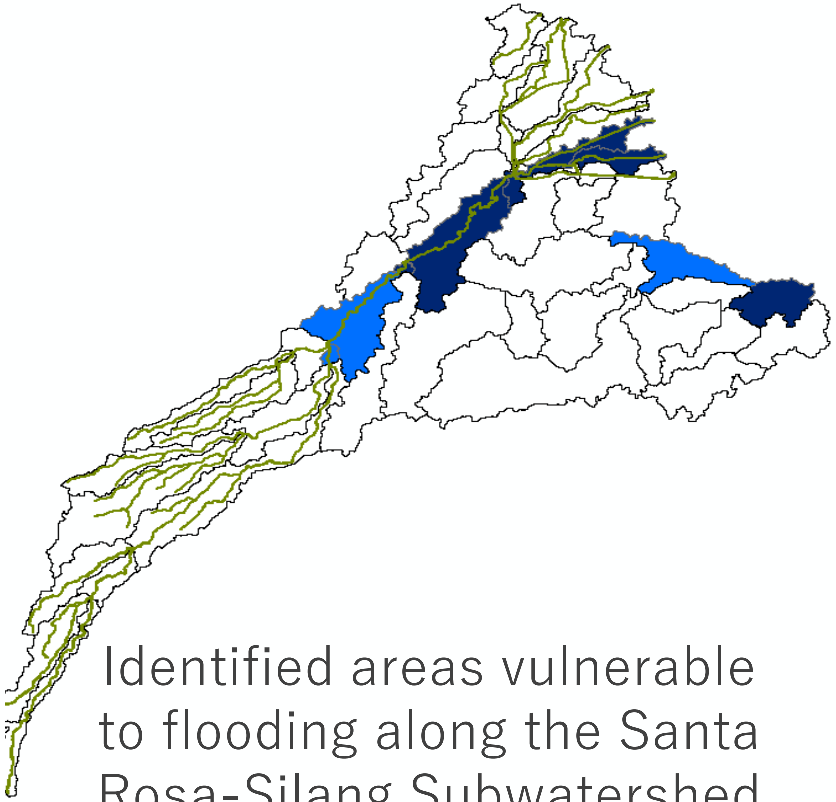


Santa Rosa-Silang Subwatershed divided into 49 dominant HRUs

Results from SWAT Modeling

- **HRU #8, #13, #15, #21, #22, and #26** are those vulnerable to flashfloods based on their physical characteristic & exposure to extreme rainfall.

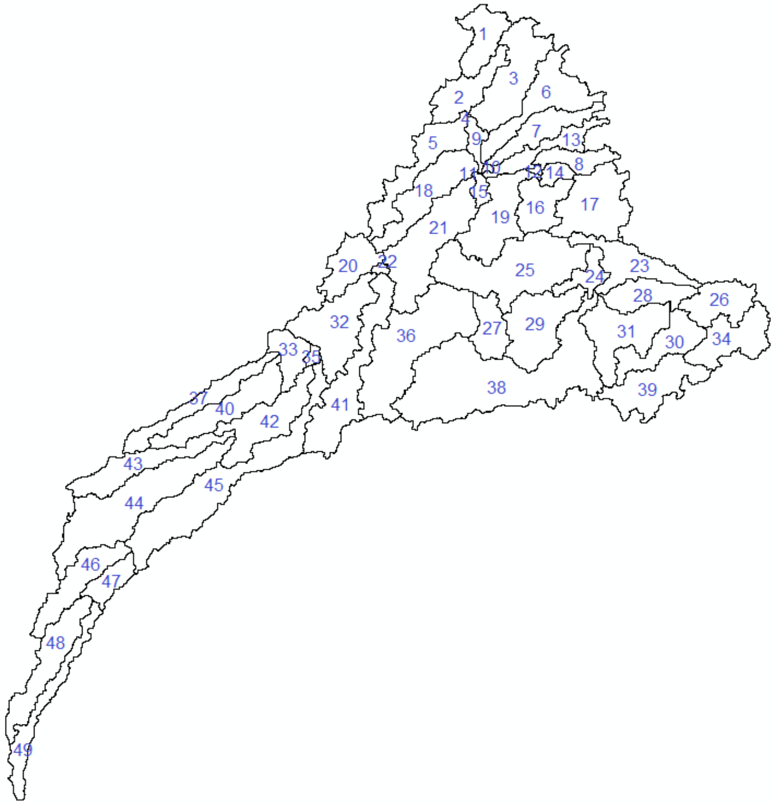


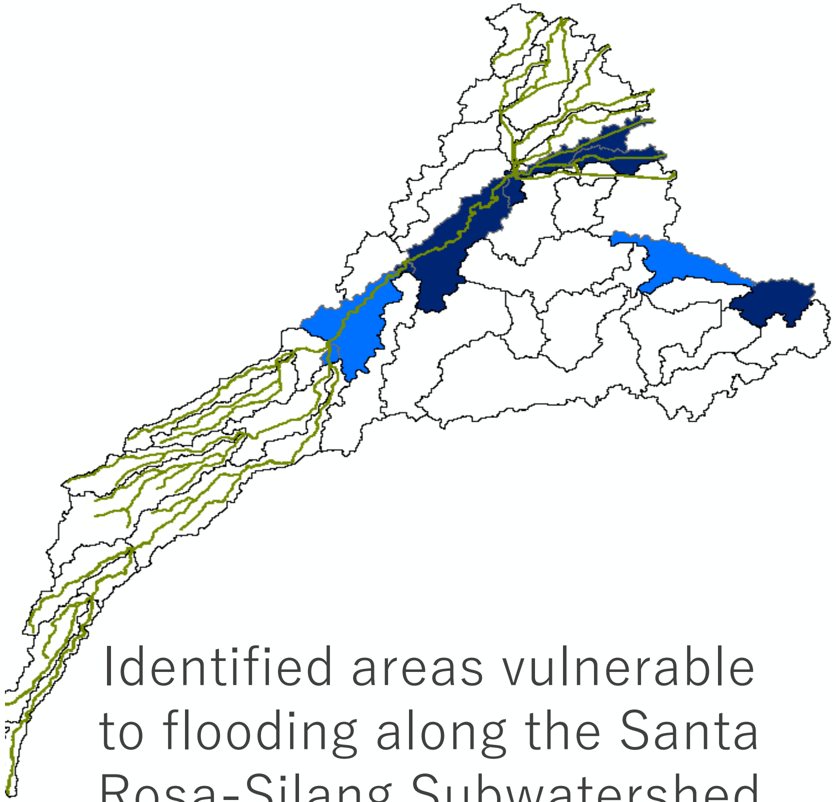


Identified areas vulnerable to flooding along the Santa Rosa-Silang Subwatershed

Results from SWAT Modeling

- **HRU #8, #13, #15, #21, #22, and #26** are those vulnerable to flashfloods based on their physical characteristics & exposure to extreme rainfall.





Identified areas vulnerable to flooding along the Santa Rosa-Silang Subwatershed

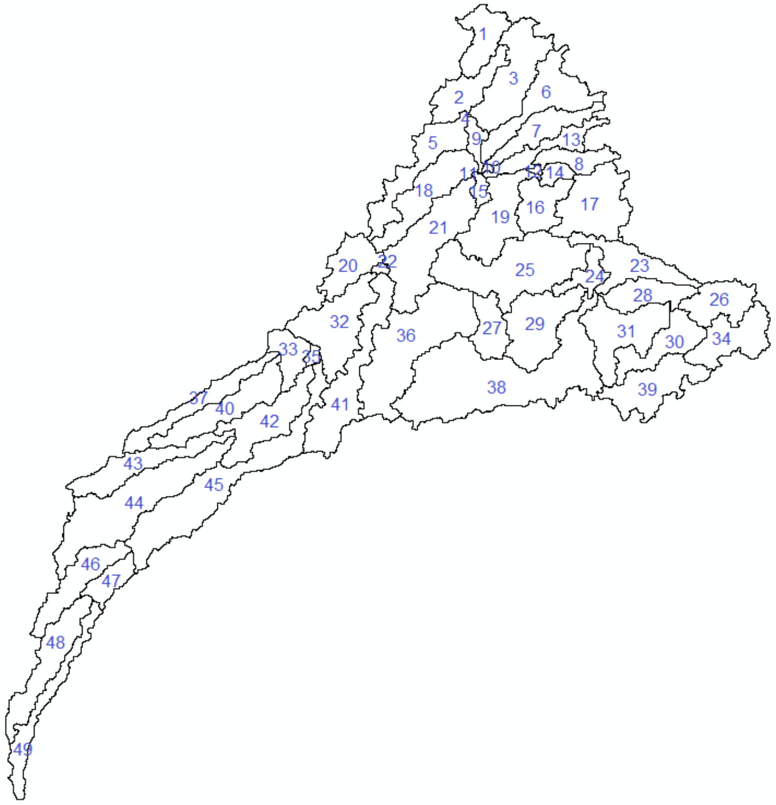
Results from SWAT

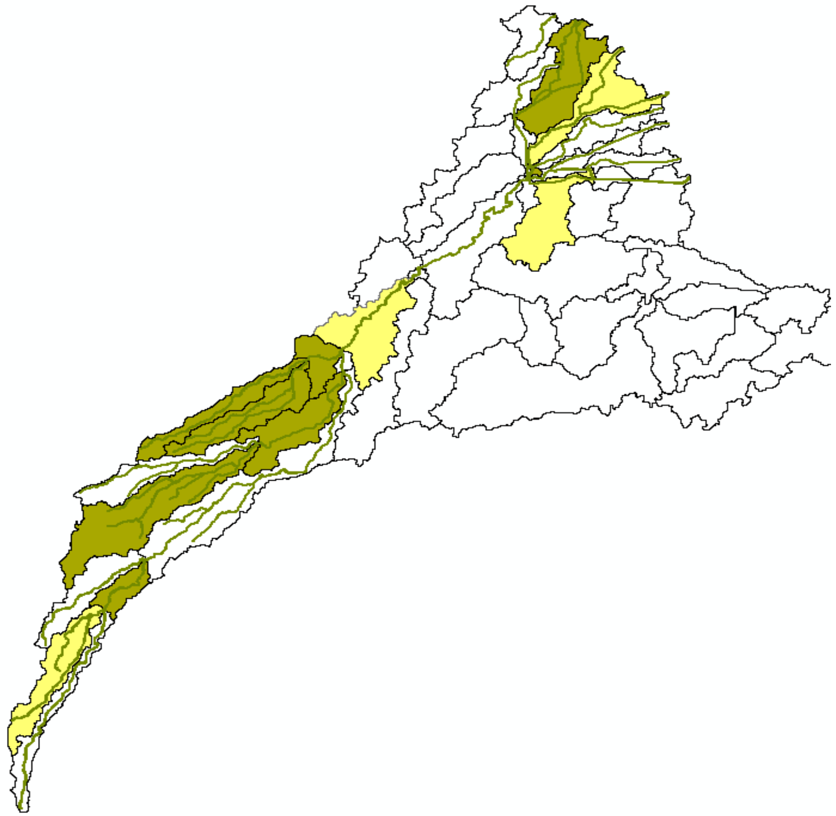
- ➢ The flooded areas are dominated by residential areas, subdivisions and built up areas which render the permeability of the land and soils to be extremely low.

Results from SWAT

- ➢ **HRU Nos. 3, 4, and 19** – vulnerable to sedimentation

- ➢ **HRU Nos. 33, 37, 40, 42, 44, and 47** are vulnerable to erosion.





Results from SWAT

Brgy. Tartaria (Upstream)

Brgy. Sto Domingo (Mid stream)

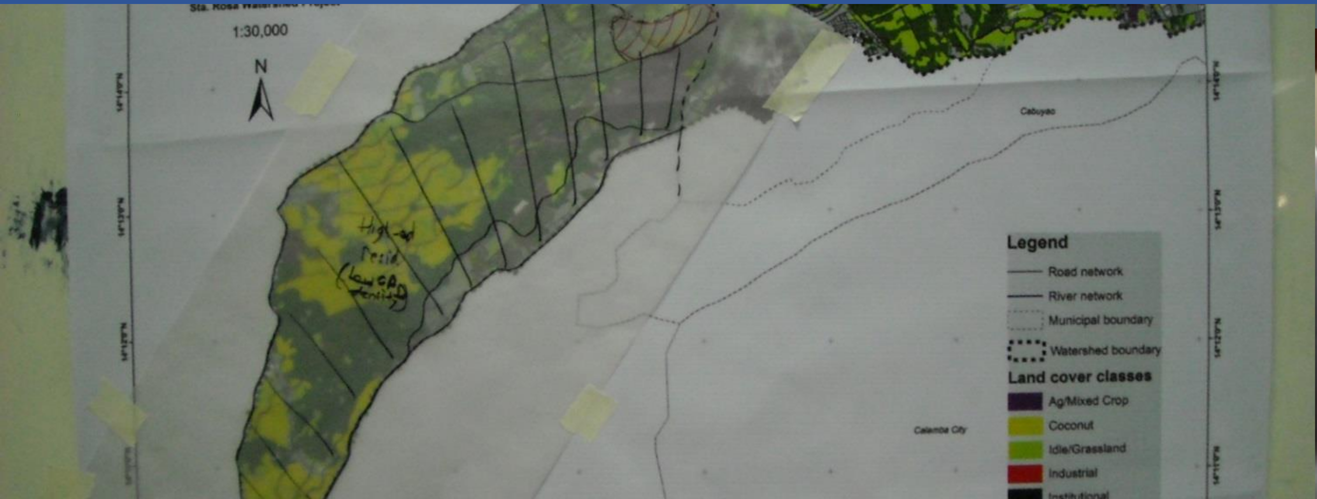
- The portions vulnerable to erosion are mostly in sloping upstream areas in Silang and midstream areas in Santa Rosa.

Results from SWAT

Brgy. Aplaya (Shoreline)

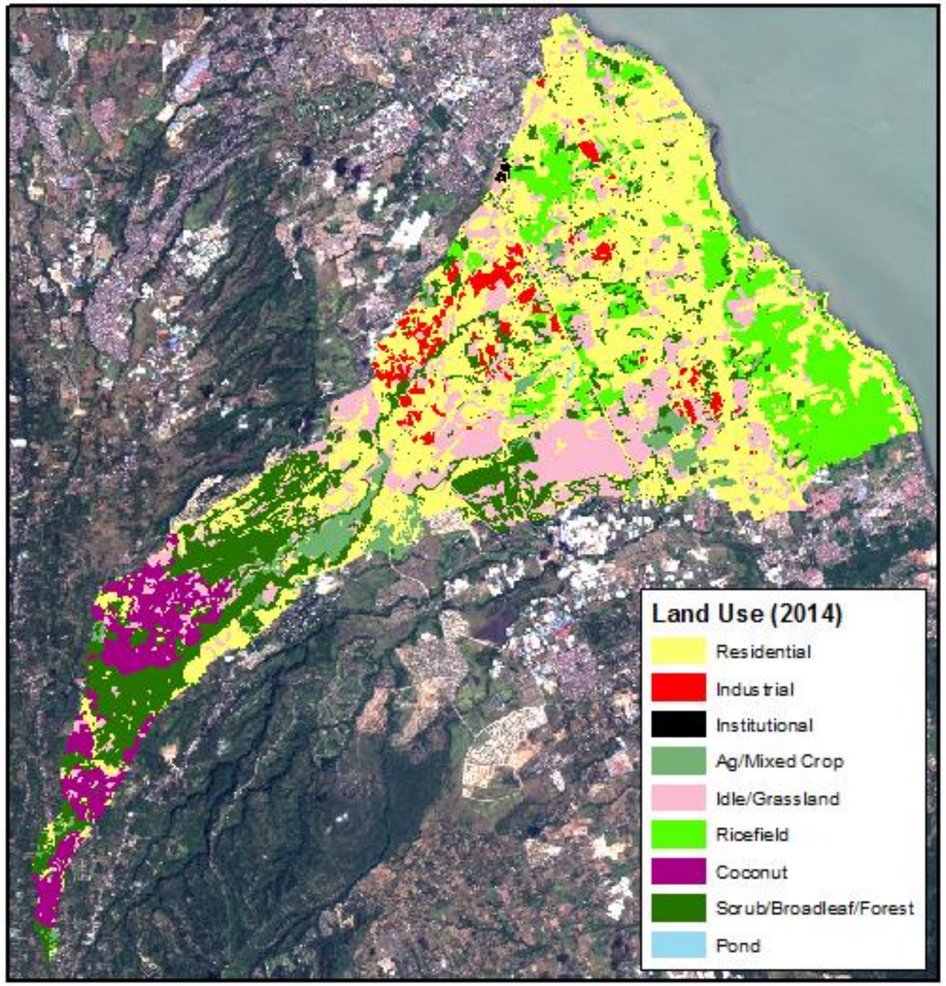
- The downstream areas along the riverine system and lakeshore are most vulnerable to sedimentation

Participatory GIS
Revealing future development & land-use

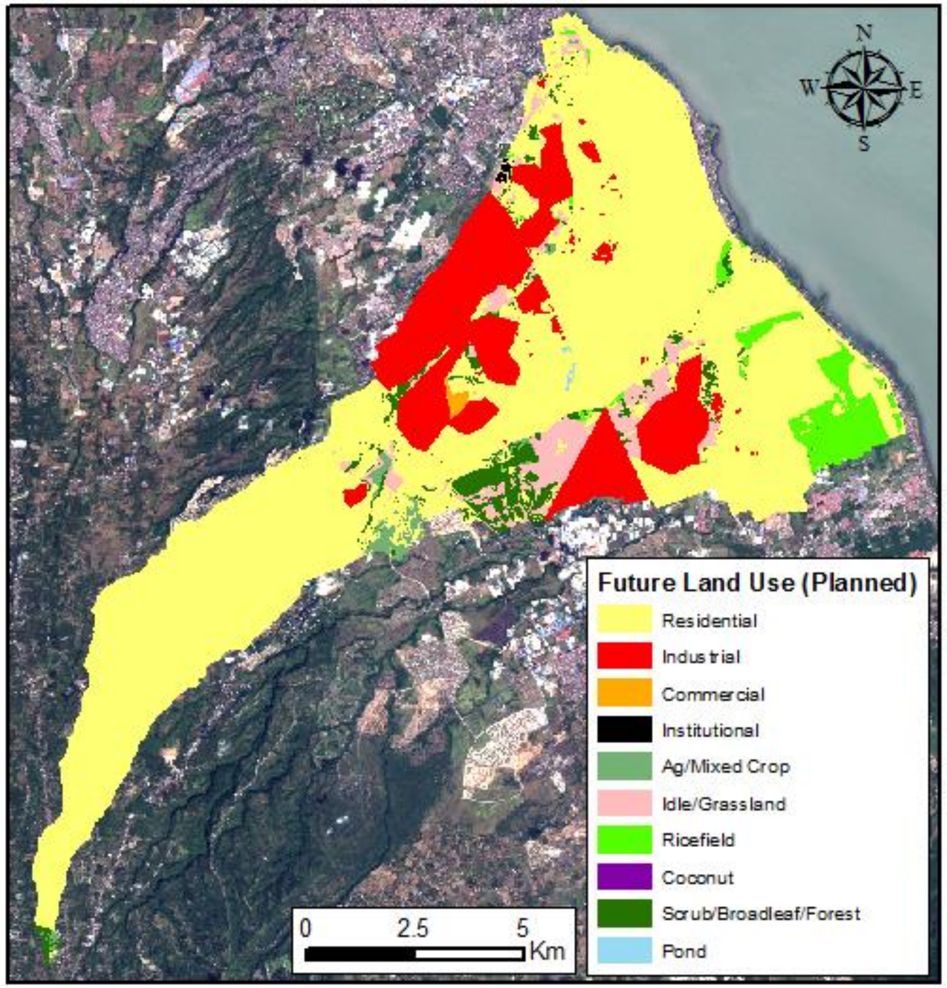


Expected change in land-use

Current Land Use (2014)



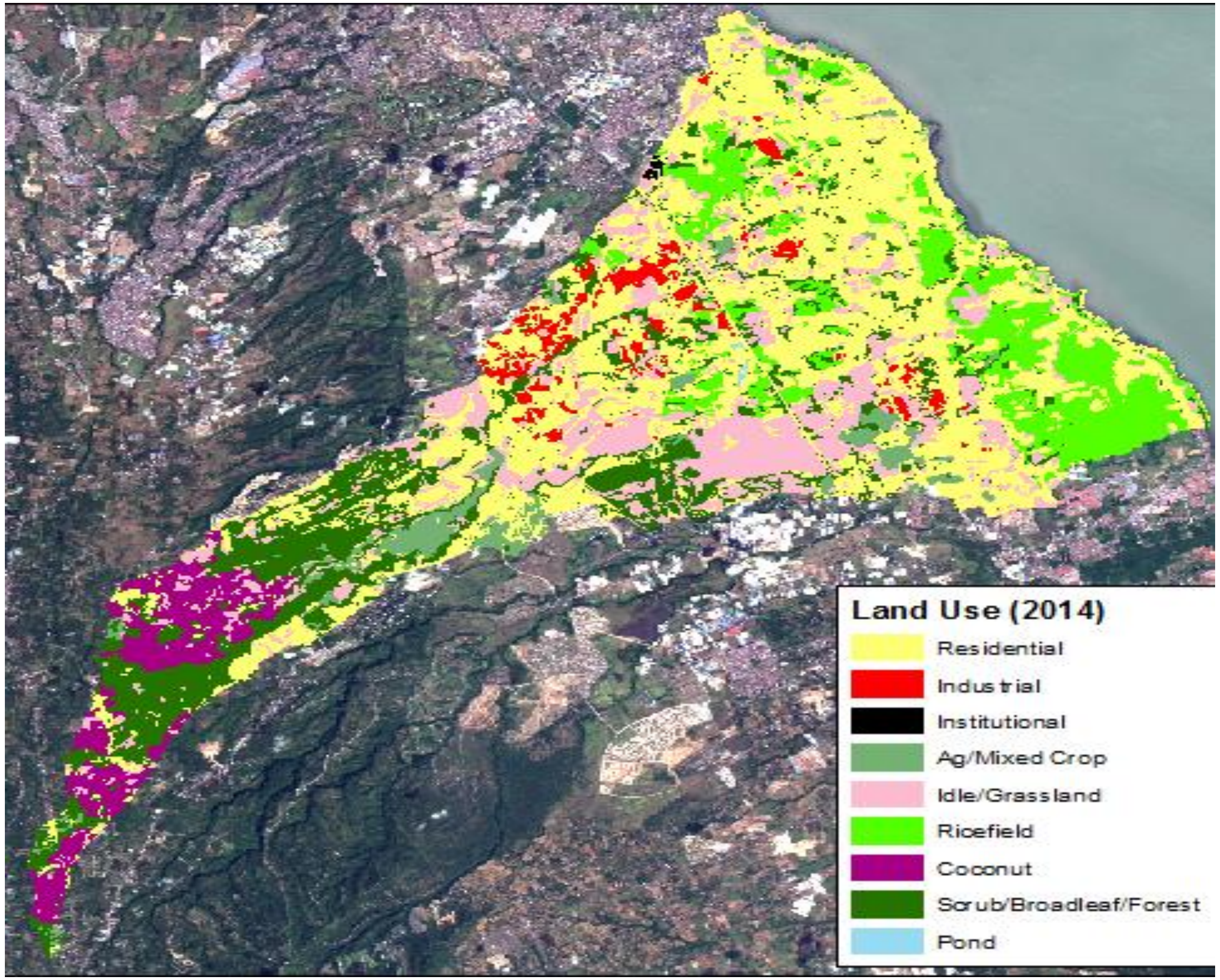
Future Land Use Plan (2025)*

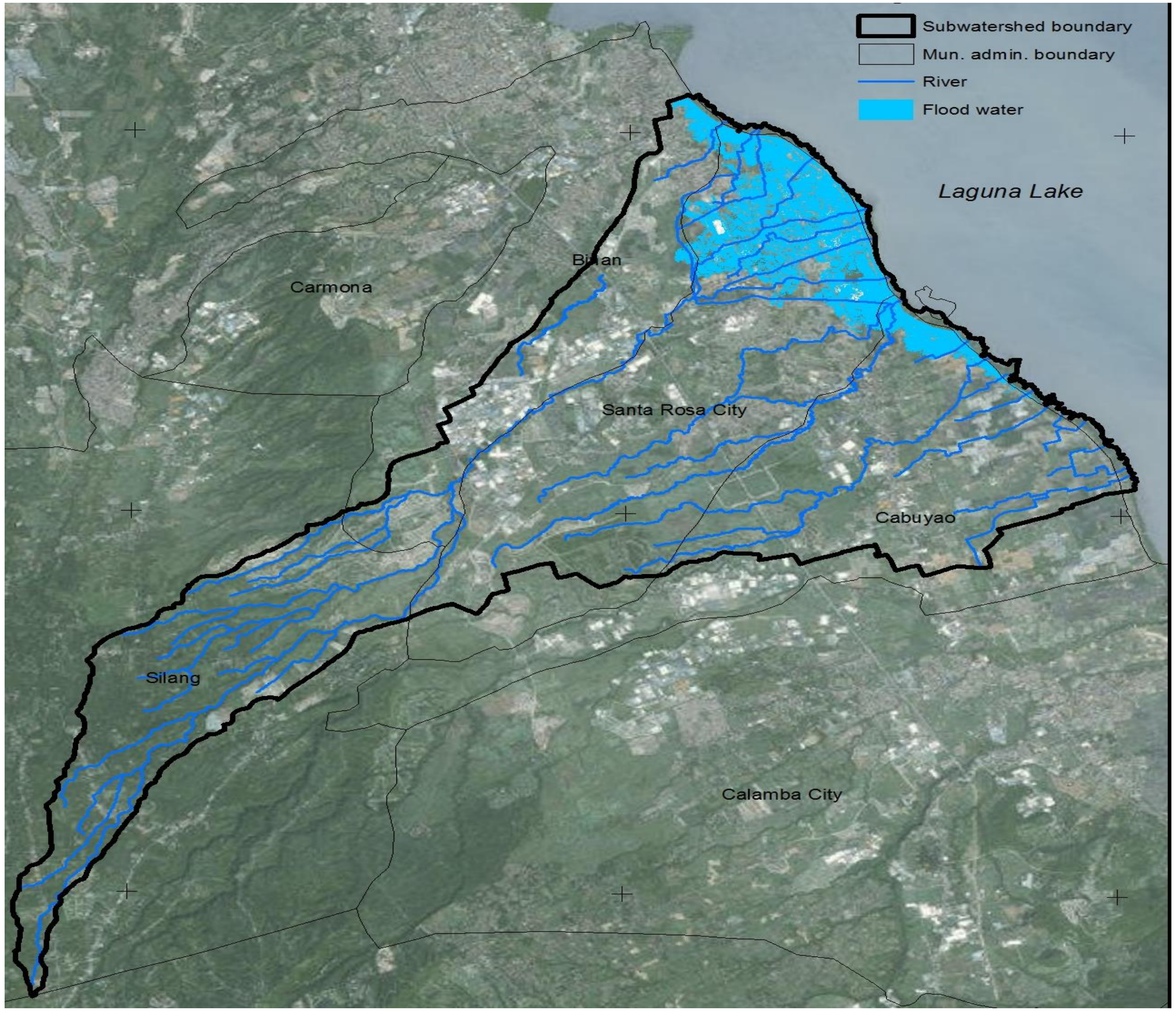


*Future land use plan map based on the results of a participatory land use mapping session with representatives from four local government units (LGUs)

Scenario Simulation: Current Scenario

Current Land Use (2014)

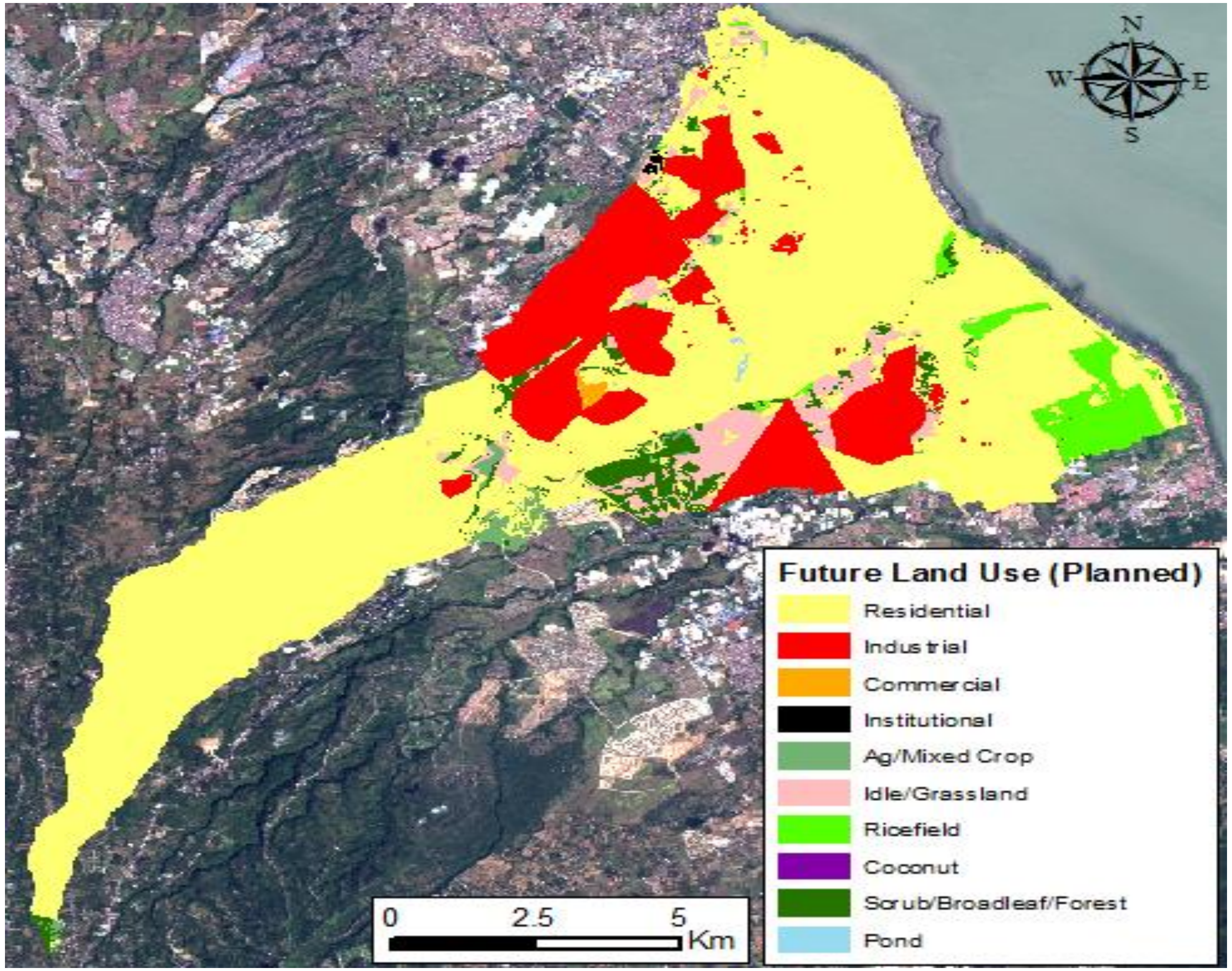


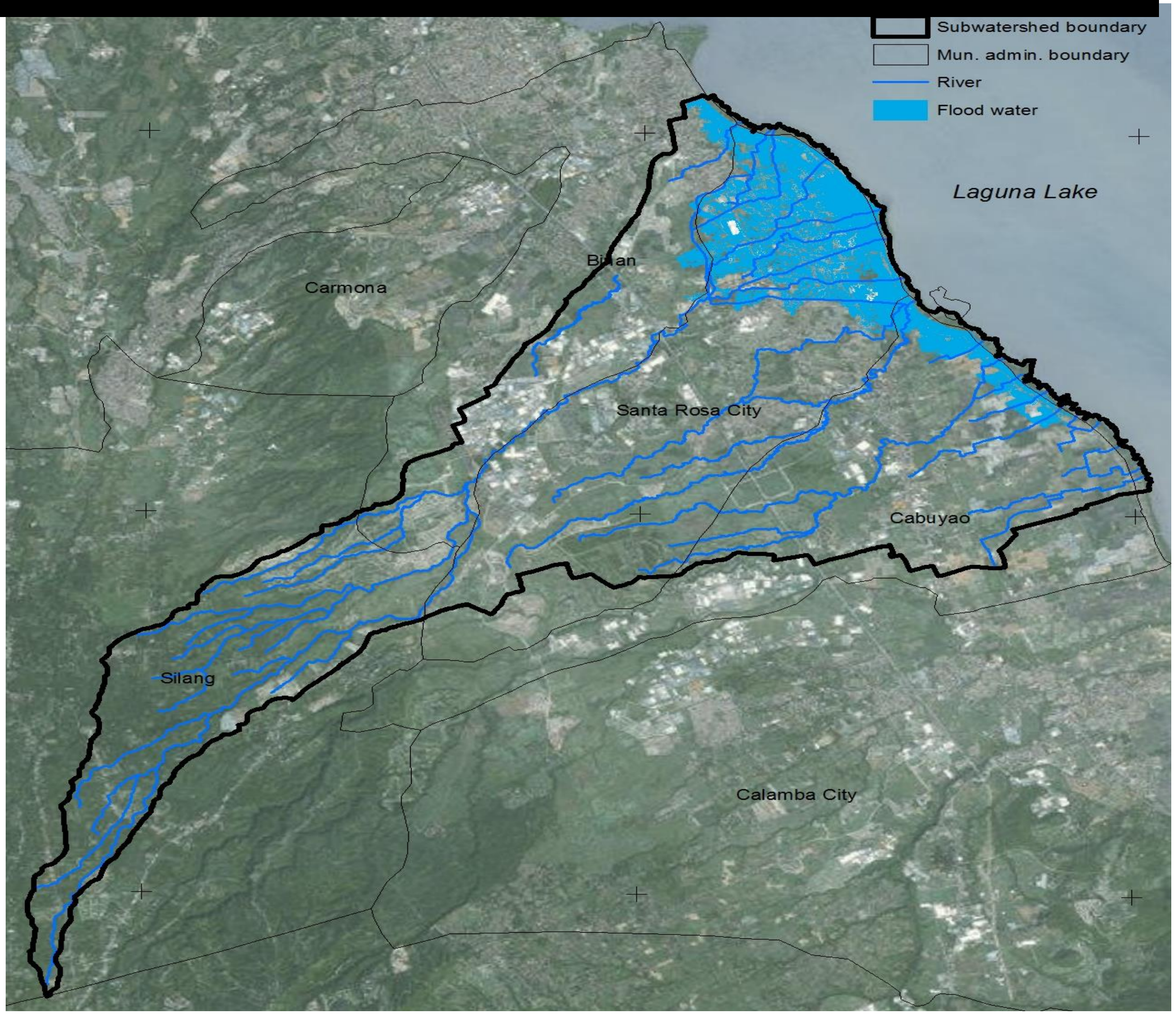


CURRENT SCENARIO (2014)
10 Year Rain Return Period

Scenario Simulation: Future Scenario

Future Land Use Plan (2025)*

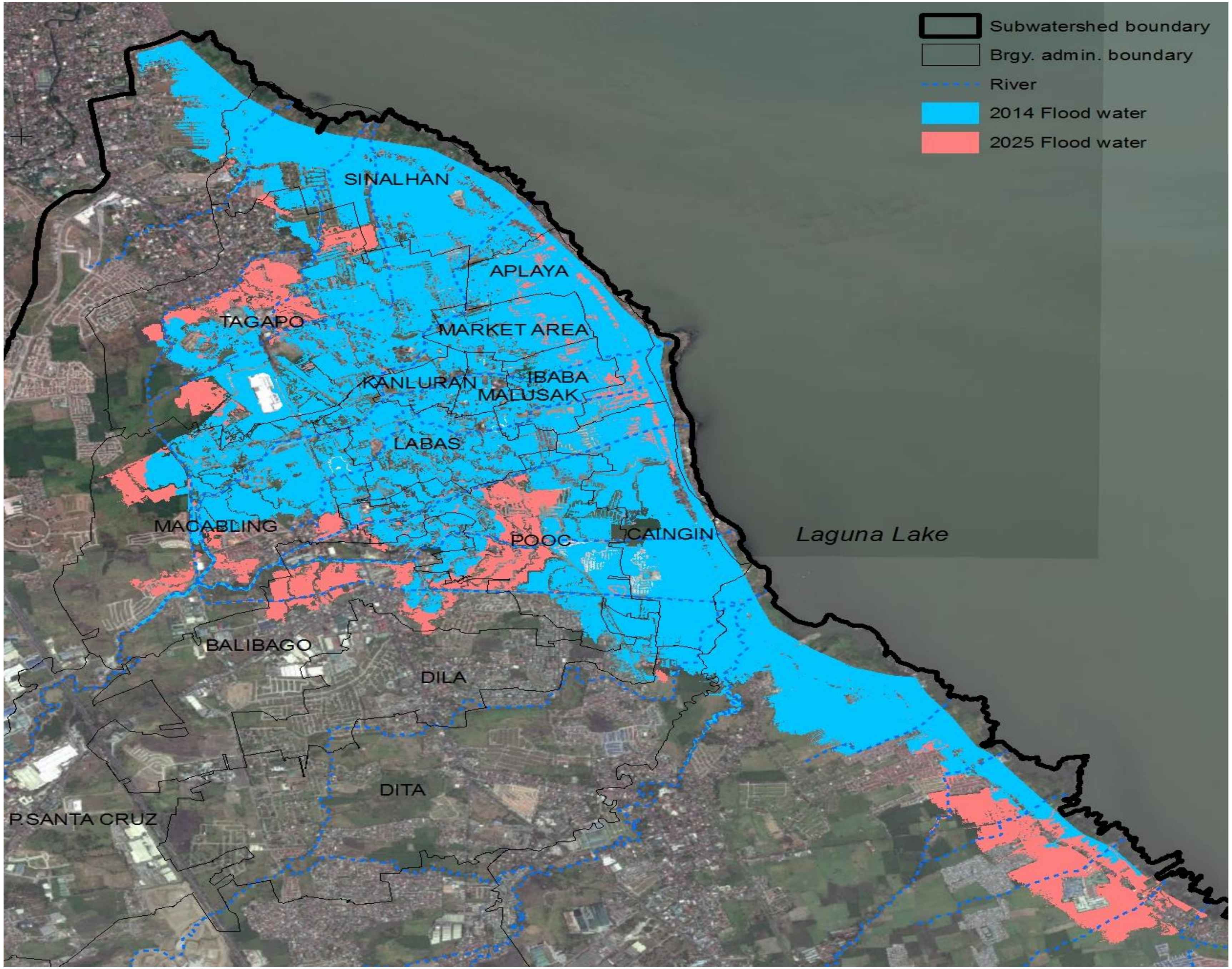




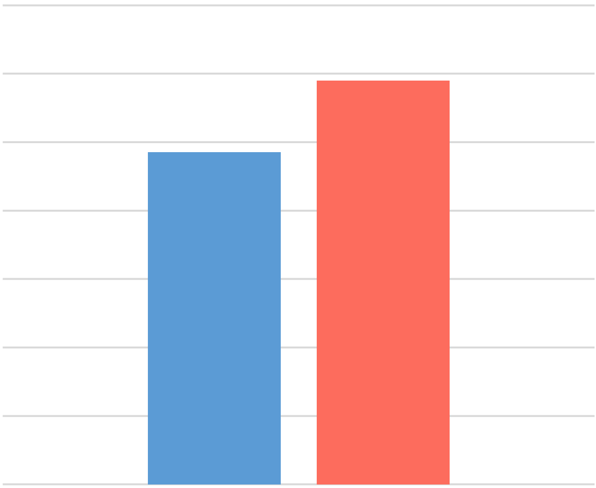
**Future land use plan map based on the results of a participatory land use mapping session with representatives from four local government units (LGUs)*

FUTURE SCENARIO (2025)

10 Year Rain Return Period

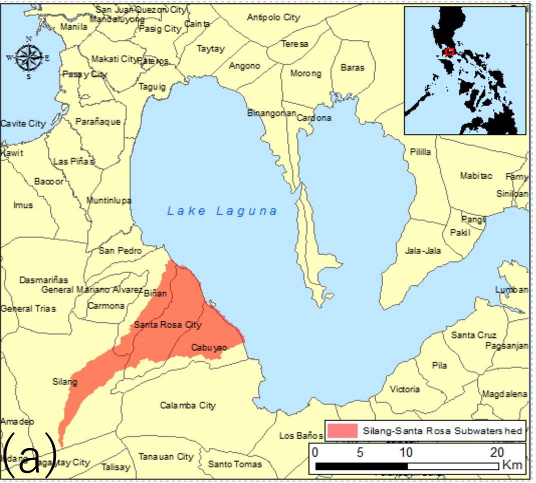


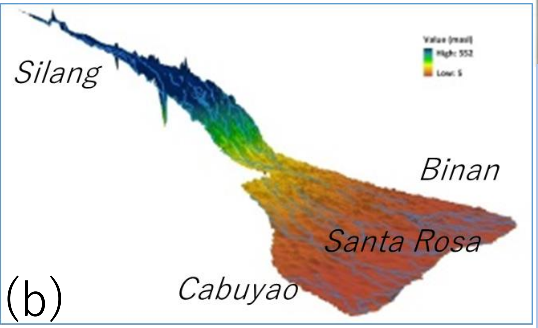
Current VS Future



	AREA (Hectares)	% increase
Current 2014	969.83	
Future 2025	1,180.12	21.68
Difference	210.29	

Scenario & risk analysis





Silang-Santa Rosa Subwatershed, Philippines
Area shaded in red (a), topography (b)

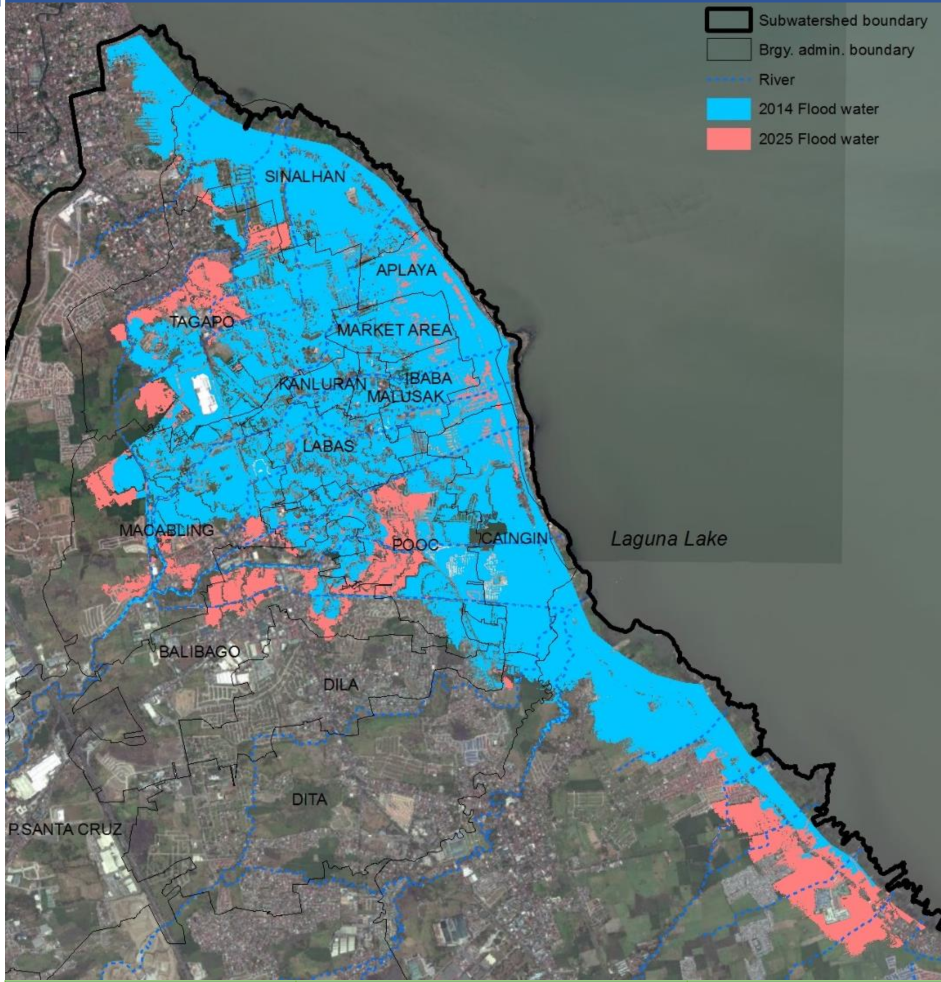
Study site

Future BAU scenario (2025)
Simulation using 10 min. time step

Rainfall: Typhoon Ofel
(Int. Name: Son-Tinh) Oct. 25, 2012
Duration: 12 hours
Amount: 224.4 mm
Intensity: 18.67 mm/hr
Collected using Tipping Bucket Rain Gauge installed in Silang, Cavite (Upstream)

10 year Rain Return Period *Based on Ambulong Station RIDF (Rainfall Intensity-Duration Frequency Curve) which has a 54 years record. Prepared by Hydrometeorological Data Application Section (HMDAS).*

Current vs Future



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Climate change measures

1. Zoning enhancement
To avoid and alleviate climate impact, and to sequestrate carbon dioxide

- Enforce **development controls** in areas highly susceptible to flooding.
- Strengthen **building codes** in high-risk areas (e.g. floodwalls, elevated flooring).
- Devise a relocation plan for informal settlers residing in flood-prone areas.
- Mandate **runoff mitigation measures** (e.g. tree planting, water-permeable paving) where development/land-conversion is made.
- Improve enforcement of zoning ordinances.
- **Harmonize land-use** among local governments to manage the river basin as a whole.

2. River rehabilitation
To increase water retaining capacity

- All areas
  - Regular river cleanup
- Upstream area
  - Protection and improvement through **replanting of endemic and indigenous plant species**
- Midstream area
  - **Rehabilitation of easement and riverbanks**
  - Construction of slope protection along riverbanks
- Downstream area
  - Dredging of sediments
  - Solid and liquid waste management
  - Planting of endemic and indigenous plant species
  - **Improvement of drainage**

3. Capacity development
To build and strengthen the ability of local government to design and implement climate actions

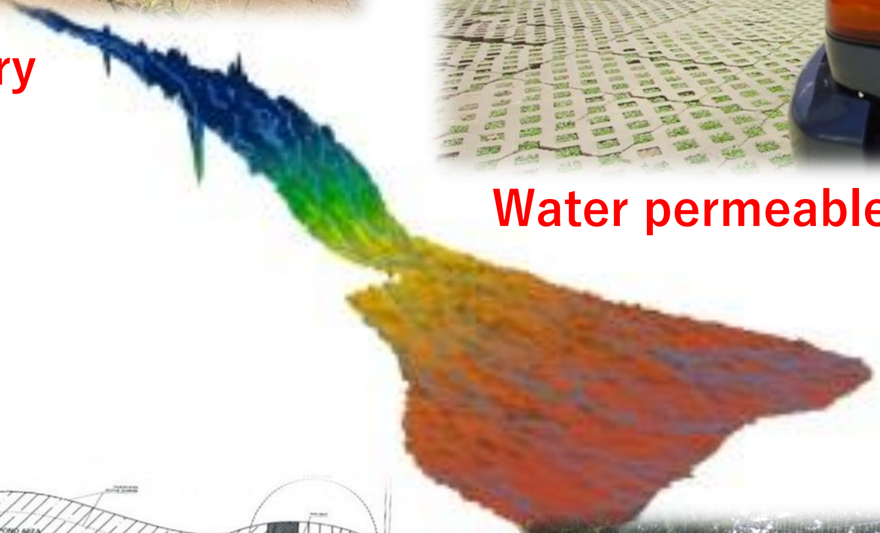
- Needs assessments on climate change adaptation and mitigation and disaster preparedness and management
- Development of campaign materials and training modules
- Conduct of trainings and events to increase awareness and preparedness

Sta. Rosa Watershed Management Council (SWMC)

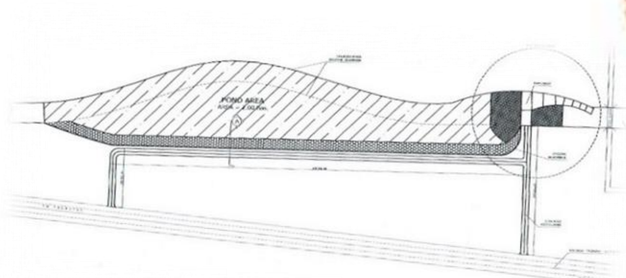
- Established in 2014 for the first time in the Lake Laguna basin
- **Aims to harmonize land-use and make collective efforts** to address weather-related disasters at the watershed level
- Consists of LLDA, LGUs as well as representatives from NGOs and the private sector
- Will create/implement the **integrated watershed management plan**

Green infrastructure / EcoDRR project idea

Agroforestry



Water permeable paving



Storm water reservoir

Urban agriculture

1. Design/evaluate green infrastructure

↓

2. Design PES system to finance green infrastructure

↓

3. Implement pilot project

↓

4. Develop stakeholder capacity

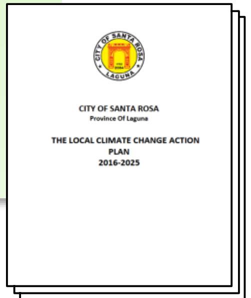
↓

5. Mainstream green infrastructure with PES system into development/land-use plan

Informing policies
Selected impacts of project implementation

Improved local planning

- ✓ Local Government Units (LGUs) in Silang-Sta. Rosa sub-watershed used project results (e.g. flood-hazard maps, countermeasures) to update **Comprehensive Land-use Plans** (CLUPs).
- ✓ City of Santa Rosa developed Local **Climate Change Action Plan** (LCCAP) using project findings.
- ✓ With project support, LGUs prepare proposal for People's Survival Fund (national funding for climate change adaptation) for implementing countermeasures.


CITY OF SANTA ROSA
Province Of Laguna
THE LOCAL CLIMATE CHANGE ACTION PLAN
2016-2025

Supported national agenda

- ✓ **Climate Change Commission** (CCC) invited Project to share knowledge at Eco-town / Community for Resilience (CORE) conference.
- ✓ **Laguna Lake Development Authority** (LLDA) used project findings in developing master plan.
- ✓ Upon request from ADB, IGES/UPLB co-organized joint workshop with ADB on urban resilience to climate change.

VULNERABILITY ASSESSMENT

Results from Community-based and key informant surveys:

Reasons For Flood Vulnerability

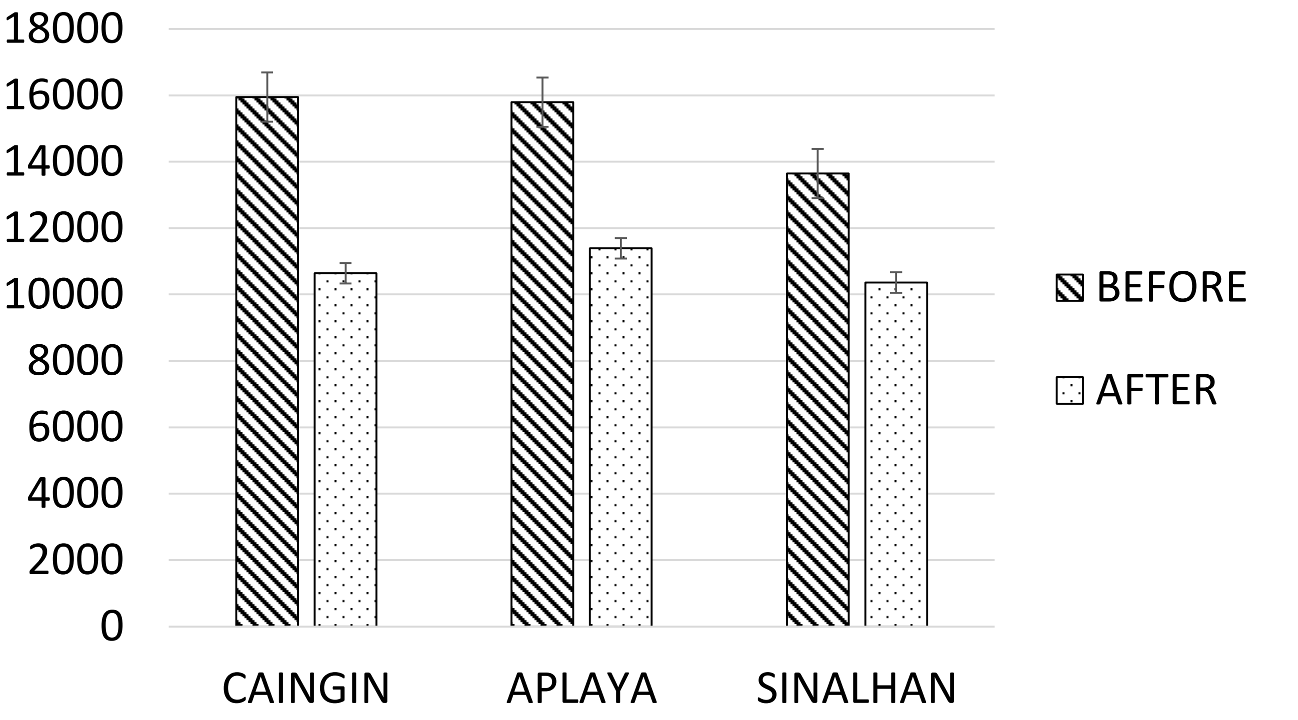
- Rapidly increasing population and population density
- Communities/Barangays have borders with the Laguna Lake.
- Most houses are within 200 m of the lake.
- Most houses are 15 years or older.
- Most houses have only one floor.

Results from Community-based and key informant surveys:

Impacts of Flooding

- Flood depth: $\geq$ 1.63
- Flood duration: Mostly 3 months
- Problems encountered during flood events are lack of electricity, lack of food, lack of drinking water and water for other uses, etc.
- Damages to house/building and minimal effect on appliance and furniture and in human health and life
- Negative impacts to livelihood and income

Impacts on Livelihood and Income:
Effect on Average Income



(14b) AVERAGE INCOME BEFORE AND AFTER FLOODS

No significant difference among values

- Most households experience a decrease in income after floods.
- Percent decrease:
  - ✓ Caingin 33.3%
  - ✓ Aplaya 27.8%
  - ✓ Sinalhan 24.0%
- Sinalhan is the least affected with no significant decrease. However, it has the lowest income of all 3 barangays.

Results from Community-based and key informant surveys:

Adaptive Capacity To Floods

- An EWS is in place at the barangay level
- Forms of government intervention and assistance are in-place
- The sanitation program, livelihood and financial programs, relief operations, evacuation and SRR operations are funded enough
- Health programs in place during and after floods are insufficient
- Furthermore, mitigation measures done by the city government and the barangays are lacking.
- However, the respondent's perception of the government interventions is **EFFECTIVE.**

Results from Community-based and key informant surveys:

Coping Mechanisms To Flood

- The residents in all barangays place valuables in high places and prepare before floods and relocate during floods.
- Most households only have medical insurance or no insurance at all.
- The respondents mainly receive financial support from relatives, friends, and neighbors.

Results from Community-based and key informant surveys:

Physical Vulnerability Analysis

BARANGAY SINALHAN

Caingin

- Height of ground
- Building

Barangay Si

- Height of ground floor
- Proximity to

Floors

Results from Community-based and key informant surveys:

Socio-economic Vulnerability Analysis

- A modified weighting matrix for

MOST

BARANGAY SINALHAN

- HIGH VULNERABILITY

MODERATE

BARANGAY CAINGIN

- MODERATE VULNERABILITY

LEAST

BARANGAY APLAYA

- LOW VULNERABILITY

Table 14. Social Vulnerability Scores/Values for Various Socio-economic Factors Using the Matrix

Factors	Weight	Social Vulnerability Class								
		Barangay Caingin			Barangay Aplaya			Barangay Sinalhan		
		Low (1) , Moderate (2), High (3)								
		1	2	3	1	2	3	1	2	3
Income	0.11									
Livelihood	0.05									
Residency	0.05									
Size of Family	0.03									
Gender	0.03									
Age	0.02									
Education	0.02									
Ownership	0.02									

Results from Community-based and key informant surveys:

Recommendations To The Local Government

- Prevention and Mitigation
- Preparedness
- Response
- Rehabilitation and Recovery

PREVENTION AND MITIGATION

- Implement and integrate DRRM and CCA principles to laws on land-use in flood-prone areas, Building Code, the National Greening Program, and existing ordinances on DRRM.
- Conduct inventory of critical infrastructure to floods by the barangays and enhance the existing mechanisms in increasing the disaster resilience of flood-reducing infrastructure and natural water systems by the city government in coordination with the barangays such as:

◆ improving and cleaning sewerage systems

◆ cleaning of rivers and the lake

◆ Building additional catch basins in spillways

◆ Building of dikes and levees near rivers and lake

PREVENTION AND MITIGATION

- Regular vulnerability assessments and hazards mapping every 3 years as recommended by the NDRRMP by the city government in coordination with the barangays
- Develop mechanisms for risk financing and insurance schemes at the barangay level to mitigate the financial effects of floods
- Developing and setting-up localized community-based Early Warning System (EWS) to enhance monitoring, forecasting and warning of flood hazards. This should include procurement of necessary equipment, building of needed infrastructure, and training of city and government officials who will eventually implement it.

PREPAREDNESS

- Perform a localized Information, Education and Communication (IEC) program at the barangay level and integrate DRRM and CCA principles in school curriculum
- Conduct training and simulation of city and barangay officials on disaster preparedness and response
- Enhance localized disaster preparedness and response systems by developing scenario-based and assessment-based action plans and policies
- Regular inventory of existing resources and services and develop a corrective action plan to improve the formulation of future plans and policies.

RESPONSE

- Ensure the activation of the incident command system (ICS) 12-24 hours before the onset of a possible flood hazard
- Ensure the activation of assessment teams within 12 hours and the use of Damage and Needs Assessment (DANA) tool within 24-48 hours of the onset of a flood hazard
- Ensure an integrated (inter-agency) and coordinate Search, Rescue, and Retrieval (SRR) operations
- Ensure the activation of evacuation mechanisms already in-place within a number of hours of flood onset
- Local government should set minimum standards of evacuation centers. Evacuation centers should have a child-friendly space for continued education and there should be a space for animals

RESPONSE

- There should be immediate medical consultation and assessment during and immediately after flood hazards
- There should be an immediate assessment of water quality
- There should be an existing list of identified health centers, clinics, and hospitals to address health concerns
- There should be a provision in the response plan to address the psychological well-being of flood victims

REHABILITATION AND RECOVERY

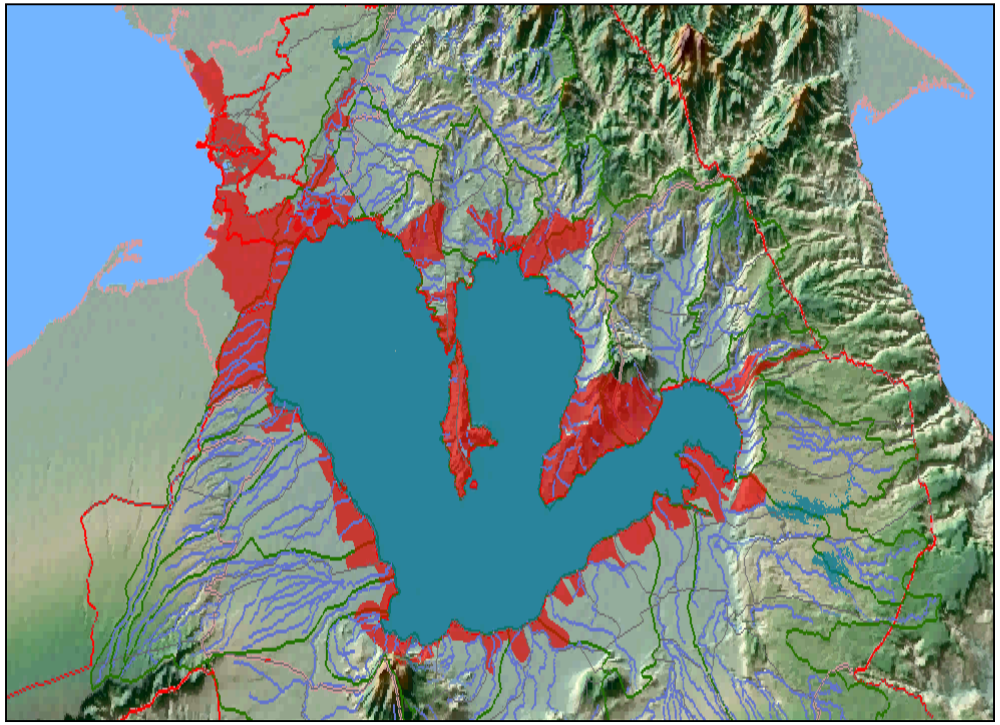
- There should be a post-disaster needs analysis to ensure that the appropriate groups receive the help they need
- Design and construct or reconstruct buildings that are disaster-resilient
- Design and implement livelihood programs and identify and mobilize funding sources for credit facilities for financial recovery
- There should be a mechanism to empower informal settlers that were displaced by floods such as construction of core shelter and cash-for-work and food-for-work programs

2018 DUBAI INTERNATIONAL AWARD FOR BEST PRACTICE

THANK YOU!

Results from SWAT

- Coastal areas around the Laguna Lake are vulnerable to increase in **lake water level rise**
- Continuous rain
- Lasts for 2-6 months
- Up to 3 meters high



Flood hazard map

in Laguna Lake Greater Watershed