THE RIDGE, RIVER TO REEF RURAL-URBAN LAND USE EVALUATION SYSTEM FOR CLIMATE CHANGE ADAPTATION AND DISASTER RISK MANAGEMENT PROJECT: MID-TERM REPORT (R^3 RULES for CCA-DRM)

PI No 309

Manila Observatory, Ateneo de Manila University, Loyola Heights Campus, Katipunan Rd., 1101 Quezon City, Metro-Manila, Philippines; Tel: (632) 426 59 21-23/59 39/59 59; Fax: (632)426 61 41/08 47

May Celine T.M. Vicente[1](celine@observatory.ph), Flordeliza P. del Castillo[1] (fpdelcastillo@observatory.ph), Emmi Capili-Tarroja[1](ebcapili@observatory.ph), Dexter S. Lo[5](d.lo@xu.edu.ph) , Ma. Antonia Y. Loyzaga [1] (aloyzaga@observatory.ph), Daniel J. McNamara, SJ[1](daniel@observatory.ph), Gemma T. Narisma[1] (narisma@observatory.ph), Ermelina G. Regis[4] (egregis@gmail.com), Mario S. Rodriguez[7] (rodriguezmars@adzu.edu.ph), Lourdes R. Simpol[6] (letsimpol@gmail.com), Quirino M. Sugon, Jr.[1] , (qsugon@observatory.ph)

[1] Manila Observatory, [4] Ateneo de Naga University, [5] Xavier University, [6] Ateneo de Davao University, [7] Ateneo de Zamboanga University

ABSTRACT

Located in the tropics within the Pacific Rim of Fire and being archipelagic, the Philippines is hazard-prone and most vulnerable to impacts of climate change. Comprehensive and Sustainable Land Use Plans or CSLUPS are important because the way we allocate land to specific functions or uses influences our exposure and susceptibility to disasters. In other terms, a significant factor affecting or contributing to cyclic, cumulative and worsening disasters is the way we use and plan for the use of land.

At the core of this research initiative and as a relevant application, is the need to develop, to impart and set-up a ridge, river to reef rural-urban land use evaluation system for climate change adaptation and disaster risk management or R^3 RULES for CCA-DRM. This R^3 concept originated from Ms. Hilly Ann Roa-Quiaoit, VP for Research and Social Outreach, and is extensively adopted in the field by Fr. Mars P. Tan SJ, both of Xavier University, also known as Ateneo de Cagayan. RS-GIS-based land use/ cover classification then represent exposure maps on the bases of which vulnerability mapping are to be undertaken. Slum detection and wider land use classification using multi-date SPOT XS (1988, 1997, 2000, 2008), SPOT P (1997), AVNIR-2 (2010), PRISM (2010) and PLASAR (2009, 2010, 2011) are foreseen in the coming months, thereby enabling the comparison of urban complexities by type of ridge, river to reef rural-urban ecosystems across politico-ecologic zones.

The next steps for Metro-Manila are groundtruthing or ground verification. Then contextual coverage with subsets of imageries of other pilot sites (i.e. Naga City, Cagayan de Oro City, Davao City and Zamboanga City) are to be taken for classification according to pre-tested processes. The hypothesis is that certain processes are better adapted to unique complexities of the ridge to reef rural-urban ecosystem.

Other upcoming tasks are historical and projected climate downscaling and mapping of associated geophysical and ecological hazards. Also, ways forward include the development of the rural-urban land use evaluation system itself, i.e., in terms of adaptiveness to climate and disaster resilience. The various combinations of optional CCA-DRM strategies are to be weighed against non-intervention via the appropriate cost-benefit analyses. Regional risk digest and profiles shall be collated in the form of a Project Case Work or PCW toolkit. The PCW Approach was conceptualized and developed by Mr. Guenter Tharun, former Director of CDG-SEAPO, Bangkok, in 1983 [1]. These PCWs are to be satellite-based risk communication products and development instruments in as much as these are also governance tools.

1. INTRODUCTION

Background and Significance of the Project

After a national assessment has been thoroughly drawn from previous province-scale maps, an important step that needs to be made is to devolve the entire vulnerability and risk mapping process to the municipal or even *Barangay* and community scales. While national hazard, exposure, vulnerability and risk maps (pegged to the province level) provide a general direction for disaster assistance efforts, such coarse-resolution disaster vulnerability information is at best limited as far as rational and actual allocation of resources is concerned.

Within a province or region, differentiated vulnerabilities do exist with some areas needing or deserving more assistance than others. Because of spatial variation at the local scale, one recognizes that it is not the entire province that is uniformly vulnerable to disasters. Hence, there is need to zoom in on particular provinces, municipalities/ cities and *Barangays* as well as to stratify settlements or land use patterns that are verified to be highly vulnerable to various types of disasters. Aggregated fine resolution maps (drawn on a city/ municipal, *Barangay* and community scale) can then be the more appropriate scientific bases for decision-support and for allocating scant resources that are needed in adapting to climate change and reducing disaster risk.

The ultimate goal of this project, R^3 RULES FOR CCA-DRM (RIDGE, RIVER TO REEF RURAL-URBAN LAND USE EVALUATION SYSTEM FOR CLIMATE CHANGE ADAPTATION-DISASTER RISK MANAGEMENT), is to mainstream climate change adaptation and disaster risk management (CCA-DRM) strategies into Comprehensive and Sustainable Land Use Planning and Plans (CSLUPs) of so-called Local Government Units or LGUs. This should integrate much-needed localized risk mapping. In this more climate-adaptive and disaster risk-sensitive land use mapping, the tools of remote sensing and geographic information systems (RS-GIS) are applied. As such, the tools enable space and evidence-based decision-support.

The main deliverable and result is a ridge, river to reef rural-urban land use evaluation system or R^3 RULES for CCA-DRM, meaning a systematic way of assessing how adaptive and risk-sensitive optional land use/ cover plans and strategies are. This R^3 concept originated from Ms. Hilly Ann Roa-Quiaoit, VP for Research and Social Outreach, and is extensively adopted in the field by Fr. Mars P. Tan, SJ, both of Xavier University, also known as Ateneo de Cagayan.

R^3 RULES for CCA-DRM is to be packaged and documented in the form of regional to local Project Case Works (PCWs). The Project Case Work or PCW Approach was originally conceptualized and developed by Mr. Guenter Tharun, former Director of CDG-SEAPO, Bangkok, in 1983 [1]. The PCWs are to be pro-active learning-by-doing tools. As such, these would involve historical, diagnostic and prognostic analyses but, in this case, of spatio-temporal nature. The aim is step-by-step resolution of actual and virtual scenarios and problems based on the better understanding of climate change impacts and disaster risk.

The consolidated PCWs shall be a toolkit for future training of planners, especially those from LGUs. The ultimate goal is to foster LGU and community awareness towards resilience as essential aspects of institutional and organizational capacity building. The PCW will also serve as a digest of regional risk profiles that capture, and so, intend to address various types of socio-environmental complexities.

For this project, we address only climate/ weather-related and associated geophysical and ecological hazards. This is intended to dovetail with the formulation of R^3 RULES for CSLUPs towards co-beneficial CCA-DRM.

LGU and community mapping that validates available thematic layers and maps shall be undertaken progressively each for hazard, exposure, vulnerability and risk under the training with the said casework approach. The case of pilot sites covered and addressed by Regional Disaster Risk GIS Consortia in Bicol and Mindanao Regions shall be demonstrated through this methodology. The suggestion is to undertake the community validation of hazard (H), exposure (E), vulnerability (V) and risk ($R \cong H \times E \times V$) [2] [3] maps progressively in the study areas. Base maps on which to consult with stakeholders and communities shall be generated with the help of existing and projected land use plans or scenarios.

<u>The Study Areas</u>

The study areas correspond to critical and strategic Regions in Bicol (Southeastern Luzon) and Mindanao (South of the Philippines), wherein Universities of the Ateneo are located. These study areas are:

- Metro-Manila, National Capital Region
- Naga City, Camarines Sur, Region V: Bicol
- Cagayan de Oro City, Misamis Oriental, Region X: Northern Mindanao
- Davao City, Davao del Sur, Region XI: Southern Mindanao
- Zamboanga City, Zamboanga del Sur, Region IX: Western Mindanao

The above study areas represent ridge, river to reef rural-urban ecosystems that experience unique climate and associated geophysical and ecological risk. R^3 RULES for CCA-DRM would help in better understanding the socio-environmental context of the said study areas and how best to address planning and development issues as by more adaptive and risk-sensitive CSLUPs.

2. THE RESEARCH PROBLEM

<u>The Problem</u>

Located in the tropics within the Pacific Rim of Fire and being archipelagic, the Philippines is hazard-prone and most vulnerable to impacts of climate change. Based on 2006 statistics, the country ranks among the top ten in terms of different parameters of human and economic impacts [4]. In effect, the country frequently suffers from climate/ weather-related, geophysical, ecological and anthropogenic disasters. For example, for climate/ weather-related hazards and corresponding disasters, we experience tropical cyclones, extreme rainfall, drought as well as El Niño-La Niña. Apart from these, other geohazards and geophysical disasters that the country faces are earthquakes, landslides, volcanic eruptions, tsunami and flooding.

Because these associated disasters impact the country in a complex way, sustainable development (SD) is likewise constrained and remains a challenge. Moreover, the complexity of what we see happening on the ground is often not adequately captured, particularly in baseline and existing land use maps through which problems are meant to be visualized. This leads to inappropriate if not ineffective planning and development instruments that seek to address problems, among them Comprehensive and Sustainable Land Use Plans (CSLUPS).

Why are CSLUPS critical then? These are important because the way we allocate land to specific functions or uses influences our exposure and susceptibility to disasters. In other terms, a significant factor affecting or contributing to cyclic, cumulative and worsening disasters is the way we use and plan for the use of land.

How Space-Based Tools Are Applied

Spatial tools, such as remote sensing and geographic information systems (RS-GIS), enable the tracking of socio-environmental problems and solutions in time and space. Yet land use/ cover detection and monitoring, as predominantly undertaken in the Philippines, especially among national, regional, provincial to local government agencies, still needs to benefit from scientific and technological advancements, as in developed countries.

Also at the core of this research initiative and as a relevant application, is the need to develop, to impart and set-up a ridge, river to reef rural-urban land use evaluation system or R^3 RULES for CCA-DRM. This would facilitate the formulation and assessment of optional Comprehensive and Sustainable Land Use Plans or CSLUPs. In the Philippines, the evaluation of land use/ cover options, according to criteria like risk reduction and sustainability, is still not widespread among LGUs. A land use/ cover evaluation system is much-needed if we are to better grasp or understand socio-environmental complexities, their problems and corresponding solutions. Moreover, the R^3 concept focuses on the study of watersheds and, as such, allows the opportunity to undertake transboundary evaluation of land use/ cover, in effect, across politico-ecologic zones. Among valuable results afforded are multi-scale perspectives/ models of sustainable development (SD) aided by RS-GIS.

R^3 RULES, in turn, should adequately respond to the requirements of co-beneficial climate change adaptation and disaster risk management (CCA-DRM), especially among the country's LGUs. In fact, disaster risk reduction or DRR could be an additional criteria among others towards more sustainable development or SD. This means that risk mapping may then be embedded into the wider socio-environmental planning framework that would guide the generation of CSLUPs all over the Philippines. But connections and linkages between hierarchies of development and framework plans are necessary to be consistent, holistic and systematic.

Contribution of Spatial Tools to Better Governance

Planning for and identifying priority areas for assistance requires knowing which specific areas or locations are most at risk to various forms of disasters. This is already aided by national-scale vulnerability and risk maps differentiated according to disaster types and described through a composite index that summarizes the information and pegs these to provinces. Areas for improvement include correlating risk with politico-ecologic zones (the union of political boundaries and ecosystems) and weighting hazards, the latter being site-specific.

But many municipalities are not institutionally prepared to nor capable of applying remote-sensing and geographic information systems or RS-GIS in order to pursue co-beneficial CCA-DRM and through it wider SD. These spatial tools and space-based methods are highly recommended because they help systematize planning and development of complex ecosystems already experiencing political and socio-economic pressures as well as disaster risk.

RS-GIS are also known to enable settlement or land use-based (sectoral) CCA-DRM. Image stratification (zoning by sectors) may subsequently be pegged to or overlaid with both smaller and wider political and administrative units. We can then overlay or cross politico-ecologic zones with other thematic maps. This facility would, therefore, aid Provincial and Local Governments greatly, since development targets and policies may be tracked in both time and space. This monitoring are undertaken especially in relation to the environment and resources, which are what need to be sustained. Also, the effectivity of plans and strategies may be assessed and surveyed progressively, so that we are able to determine and weigh successes against failures.

3. BENEFITS AND IMPACTS

Partners

Main partners of the project, thus far, are the following: Manila Observatory, Ateneo de Naga University (ADNU), Xavier University (XU), Ateneo de Davao University (ADDU), Ateneo de Zamboanga University (ADZU), JAXA Advanced Land Observation System (JAXA ALOS) and Planet Action.

Beneficiaries and Target Groups

The main beneficiaries are relevant stakeholders and communities as affected by so-called Comprehensive and Sustainable Land Use Plans that are, in turn, prepared by LGUs. It is intended that optional CSLUPs and strategies would be rendered more climate-adaptive and disaster risk-sensitive. Cost-benefit analyses of CSLUPs and strategies would be undertaken to compare the best options against non-intervention.

Local Actions and Impact

The foremost contribution of the R^3 RULES for CCA-DRM project in terms of local action is the development of a practical tool in the form of a project case work or PCW that LGUs can adopt, develop and learn from. In addition, step-by-step validation by LGUs, other stakeholders and communities is advocated. The PCW tool kit then becomes a development instrument but one towards better convergence.

Furthermore, space and evidence-based decision-support, leading to the systematic formulation of comprehensive and sustainable land use plans or CSLUPs, is demonstrated. The complexity of ground conditions may be better captured, visualized and analyzed through the tools of RS-GIS. As a result, more realistic and realizable development options may be weighed according to predetermined criteria. In the Philippine context, such criteria are closely associated with the LGU's respective vision-mission. In effect CSLUPs become a better reflection of this through the application of RS-GIS. CSLUPs may also be benchmarked and monitored in time and space.

The PCW tool kit would also help harmonize these CSLUPs across cities and municipalities in the country. When these are upscaled and aggregated, the preparation and integration of regional physical framework development plans would be greatly facilitated.

Although indicative, being community-based, the output maps and associated information will form the scientific bases for the efficient and prospective deployment of resources for CCA-DRM. In addition, the project shall demonstrate and facilitate the formulation of adaptation options towards risk-sensitive and sustainable development at the local scale.

4. OBJECTIVES AND EXPECTED RESULTS

Overall objective:

To foster and sustain regional collaboration towards space-based decision-support systems (DSSs) that enable the evaluation of optional ridge to reef rural-urban land use/ cover within ecosystems according to their adaptability to climate change and the reduction of disaster risk

Specific objectives:

1. To downscale and map climate/ weather-related as well as associated geophysical and ecological hazards (H), exposure (E) and vulnerability (V) towards integrated risk assessment ($H \cong E \times V \times R$), which is based on UNDP 2004 and UNDRO 1979 [2] [3]
2. To formulate optional climate change adaptation and disaster risk management (CCA-DRM) strategies and integrate these in Comprehensive and Sustainable Land Use Planning and Plans (CSLUPs)
3. To develop a Ridge, River to Reef Rural-Urban Land Use/ Cover Evaluation System (R^3 RULES) towards more sustainable development (SD) and resilience

Expected results:

- Institutional capacity building for DSSs integrating HEVR analyses
- R^3 RULES for CCA-DRM
- Compilation of Project Case Works (PCWs) as a toolkit of/ for CSLUPs and optional CCA-DRM strategies

5. MAIN ACTIVITIES AND SUSTAINABILITY

Main Project Activities

1. Design and development of sectoral Decision-Support Systems or DSSs
2. Integrated Hazard, Exposure, Vulnerability and Risk or HEVR mapping via RS-GIS
3. Project Case Work (PCW) on optional CCA-DRM strategies for CSLUPs

Main Implementing Partners and Beneficiaries

Within MO, the project is a cross-program initiative, that is, between the Geomatics for Environment and Development Program, Center for Environmental Geomatics (GED-CEG) and the Regional Climate Systems Program (RCS). GED-CEG has RS-GIS facilities while RCS has climate downscaling facilities. Regional Disaster Risk GIS Consortia are formed through Academic Hubs/ Nodes, for which a MOU of 5-year duration was forged end-2010. These GIS Academic Hubs/ Nodes are:

- Manila Observatory, Metro-Manila, National Capital Region
- Ateneo de Naga University (ADNU), Naga City for Camarines Sur Province (Region V: Bicol) – San Miguel Bay-Philippine Sea-Northeastern Pacific Seaboard
- Xavier University (XU), Cagayan de Oro City for Misamis Oriental Province (Region X: Northern Mindanao – Macajalar Bay-Bohol Sea-Visayan Sea
- Ateneo de Davao University (ADDU), Davao City for Davao del Sur (Region XI: Southern Mindanao) – Davao Gulf-Southeastern Pacific Seaboard
- Ateneo de Zamboanga University (ADZU), Zamboanga City for Zamboanga del Sur Province (Region IX: Zamboanga Peninsula, Western Mindanao) – Sulu Sea and Moro Gulf-Celebes Sea

Regional Disaster Risk GIS Consortia shall be composed not only of the abovementioned academic partners and other academic institutions but also Provincial Government Agencies, Local Government Units, NGOs and INGOs as well as other relevant stakeholders benefiting from space-based tools.

This RULES for CCA-DRM project is supported through the extended JAXA ALOS (Advanced Land Observation Satellite) Research Agreement. In addition, RULES for CCA-DRM was accepted to benefit from in-kind grants by Planet Action, an open initiative spearheaded by SPOT Image, CNES (the French Space Agency), together with Digital Globe (QuickBird), ESRI, (ArcGIS: ArcView, ArcEditor, Arc-Info), ITTVIS (ENVI) and Trimble Geospatial Munich (e-Cognition). This project then features utilization of the ALOS products, namely AVNIR-2, PRISM and PALSAR, and merging these together with SPOT imageries. SRTM and LANDSAT are likewise used, especially for context analyses and SPOT for the priority study areas.

Sustainability and Multiplier Effects

The collaboration with Regional Disaster Risk GIS Academic Hubs/ Nodes is based on long-term sustainability and upscaling. The MOU with them enables not only scientific and research collaboration but counterparting (i.e. Hardware, software, human resources and systems management) as well as networking through local partnerships. Consortia are to be engaged to include Local and Provincial Governments towards sustainable development or SD initiatives and resilience.

Funding support for the broader collaborative program and its project components continues to be sought. Currently this is provided through the Christian Aid (CA) as well as the UNESCO, that is, in the case of related studies concerning Metro-Manila.

Downstream and upstream as well as regional to local multiplier effects are expected arising from the establishment of Regional Disaster Risk GIS Consortia in the abovementioned study sites fuelled by the Academic Hubs/ Nodes. These include technology transfer, human resource development, information architecture and systems design and maintenance, research collaboration and knowledge development.

6. RESEARCH AND IMAGE PROCESSING METHODOLOGY

Hazard Mapping

Climate/ weather-related downscaling and geophysical hazard mapping are still on-going as of the moment and are expected to take about two to three years parallel to exposure and vulnerability mapping all in all towards integrated risk assessments for various pilot sites.

The following flow diagram illustrates the detection of flooding using pre and post-flood ALOS PALSARs downloaded from the Sentinel Asia Website. The subsequent image shows the flooding in the Eastern portion of Metro-Manila.

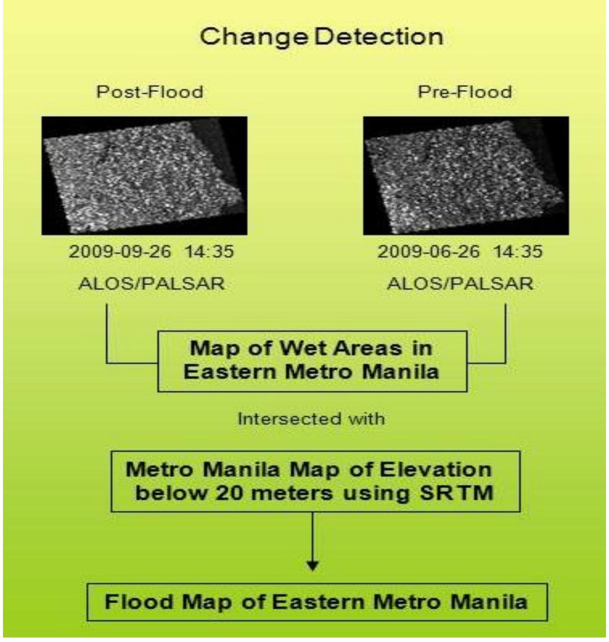


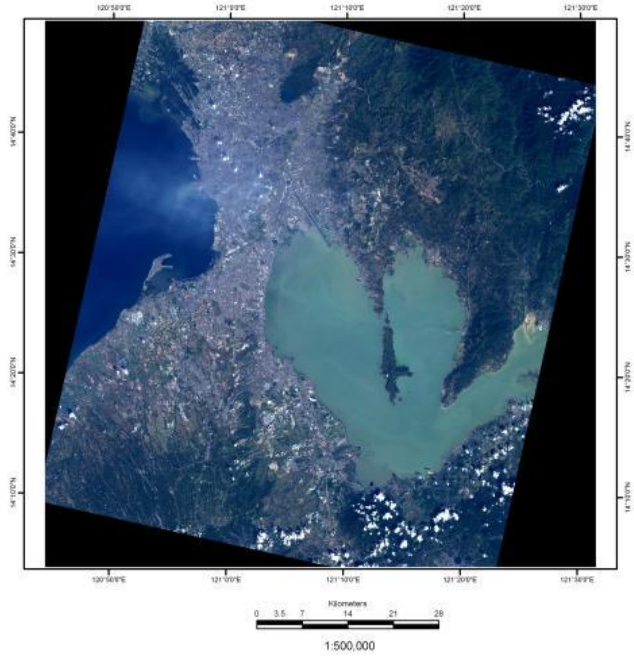
Fig. 1 Detection of Flooding Using PALSARs

Fig. 2 Footprint of Flooding over Google Image of Metro-Manila

Exposure and Vulnerability Mapping

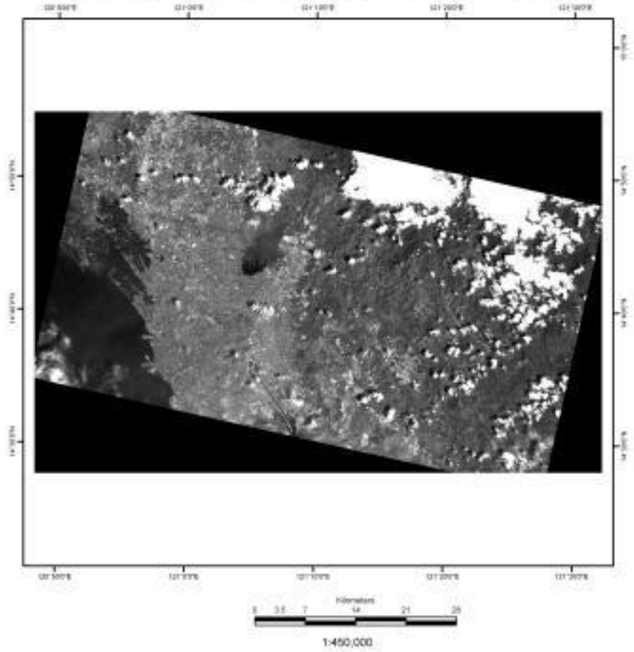
Processing of imageries of Metro-Manila are among the major steps of the project. The intention is to apply various techniques for multi-temporal and multi-scale land use/ cover classification and then to compare across ridge, river to reef rural-urban ecosystems by level of complexity. The ultimate goal is to determine CCA-DRM options and their respective cost-benefit, that is, with respect to non-intervention. CCA-DRM mix of strategies and their corresponding evaluation are to be in the form of maps. Different types of satellite imageries are used in the case of Metro-Manila: SRTM 90 (2000), SPOT XS (1988, 1997, 2000, 2008), SPOT P (1997) and ALOS satellite products, namely, PALSAR (2009, 2010, 2011), PRISM (2010) and AVNIR-2 (2010).

METRO MANILA
ALOS AV2 A D0933310 0 1B2 02Feb10.tif



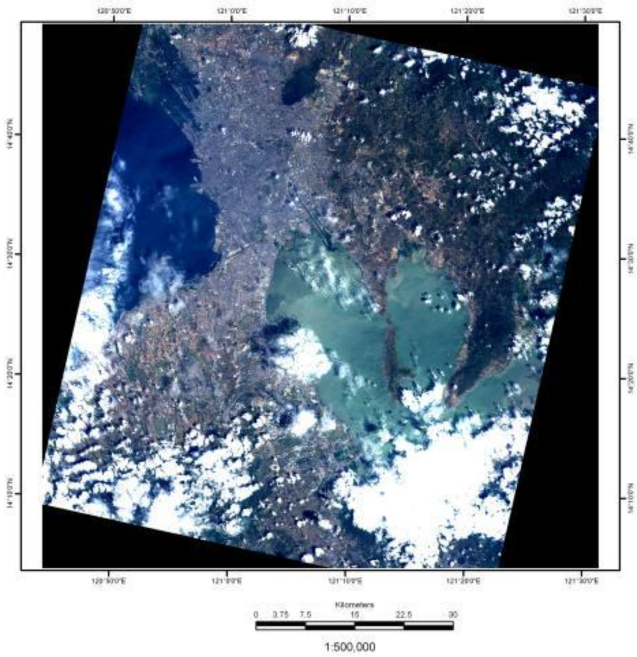
SATELLITE IMAGERIES	DATE	AREA COVERAGE	EXTENT (degrees)				PROJECTION	DATUM	SPATIAL RES	ENERGY RANGE (BAND NO.)				
			N		E				meters	R	G	B	IR	NIR
			TOP	BOTTOM	LEFT	RIGHT								
ALOS AVNIR-2	Feb-10	METRO MANILA	14.82994957	14.0721316	120.7426301	121.5268537	UTM, ZONE 51N	WGS-84	10	3	2	1		4

METRO MANILA
ALOS PSM W D0933305 0 1B2 20Mar10.tif



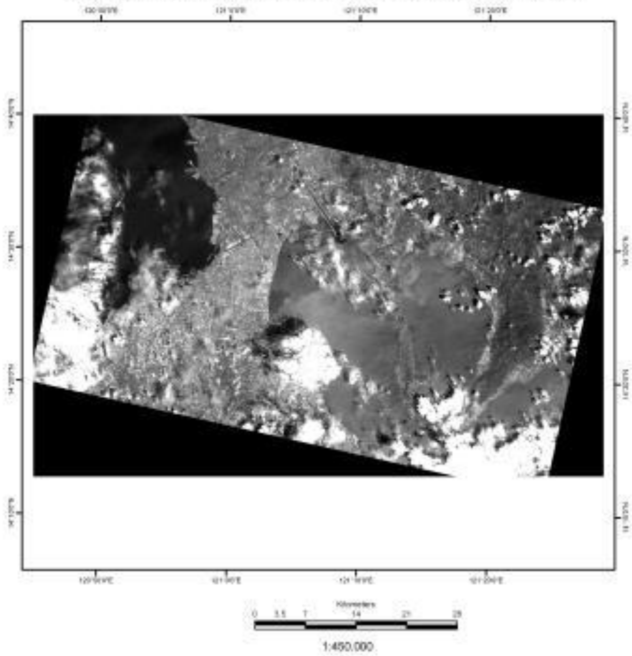
SATELLITE IMAGERIES	DATE	AREA COVERAGE	EXTENT (degrees)				PROJECTION	DATUM	SPATIAL RES
			N		E				meters
			TOP	BOTTOM	LEFT	RIGHT			
ALOS PRISM	Mar-10	METRO MANILA	14.67285341	14.21826023	120.751898	121.4833557	UTM, ZONE 51N	WGS-84	2.5

METRO MANILA
ALOS AV2 A D0933310 0 1B2 20Mar10.tif



SATELLITE IMAGERIES	DATE	AREA COVERAGE	EXTENT (degrees)				PROJECTION	DATUM	SPATIAL RES
			N		E				meters
			TOP	BOTTOM	LEFT	RIGHT			
ALOS AVNIR-2	Mar-10	METRO MANILA	14.82947351	14.0717229	120.7397681	121.5239875	UTM, ZONE 51N	WGS-84	10

METRO MANILA
ALOS PSM W D0933310 0 1B2 20Mar10.tif

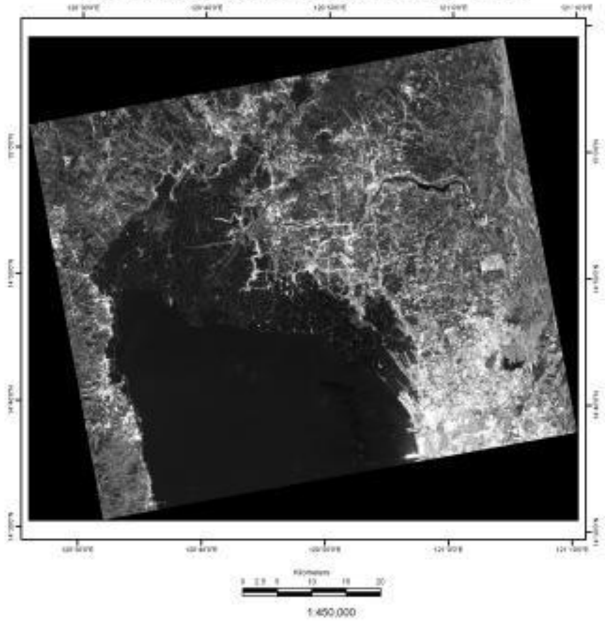


SATELLITE IMAGERIES	DATE	AREA COVERAGE	EXTENT (degrees)				PROJECTION	DATUM	SPATIAL RES
			N		E				meters
			TOP	BOTTOM	LEFT	RIGHT			
ALOS PRISM	Mar-10	METRO MANILA	14.93146513	14.46797824	120.8084101	121.5386737	UTM, ZONE 51N	WGS-84	2.5

Fig. 3 ALOS AVNIR-2 of Metro-Manila

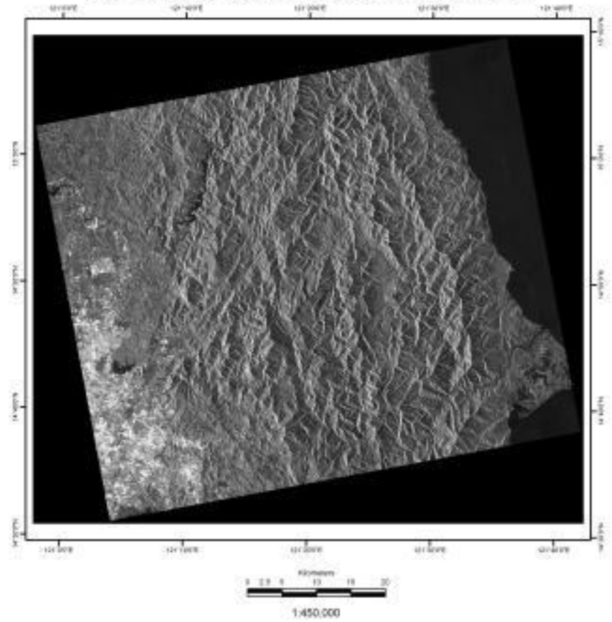
Fig. 4 ALOS PRISM of Metro-Manila

METRO MANILA
ALOS PSR 1.5 2010-02-28 14-37-44.tif



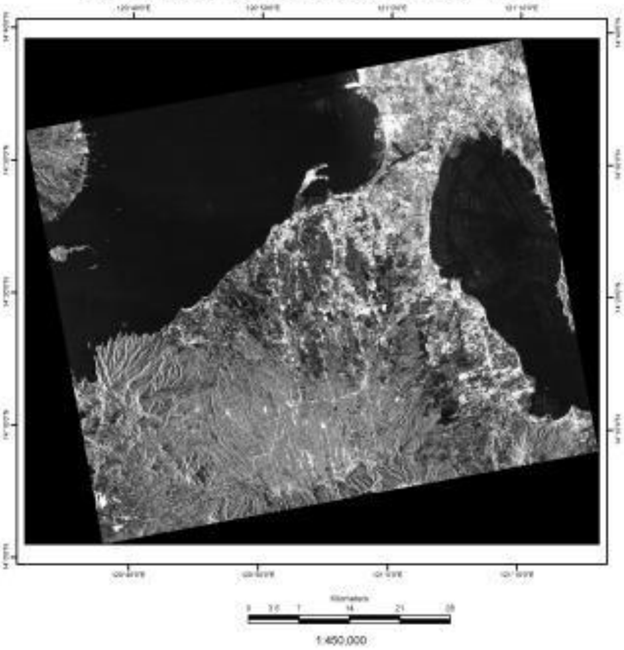
SATELLITE IMAGERIES	DATE	AREA COVERAGE	EXTENT (degrees)				PROJECTION	DATUM	SPATIAL RES
			N		E				meters
			TOP	BOTTOM	LEFT	RIGHT			
ALOS PALSAR	Feb-10	METRO MANILA	15.15002073	14.51855856	120.4333027	121.1752232	UTM, ZONE 51N	WGS-84	8.25

METRO MANILA
ALOS PSR 1.5 2010-06-29 14-34-30.tif



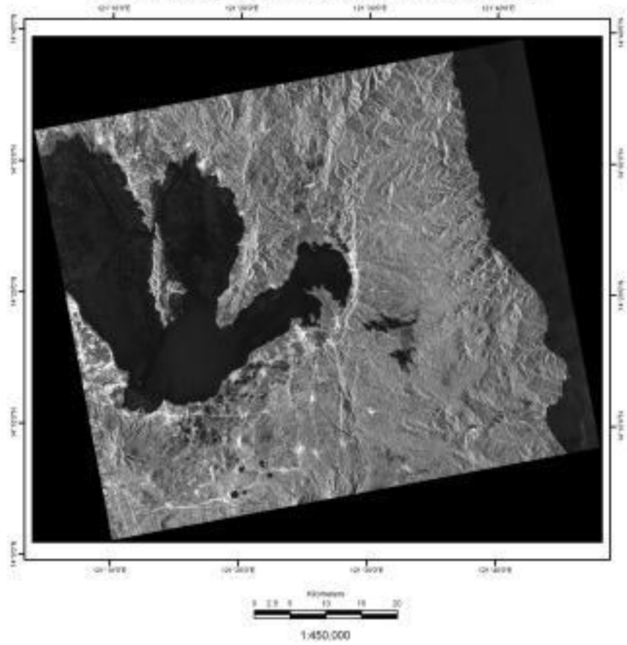
SATELLITE IMAGERIES	DATE	AREA COVERAGE	EXTENT (degrees)				PROJECTION	DATUM	SPATIAL RES
			N		E				meters
			TOP	BOTTOM	LEFT	RIGHT			
ALOS PALSAR	Jan-10	METRO MANILA	17.70618698	13.63543646	118.4258275	122.4880173	UTM, ZONE 51N	WGS-84	12.5

METRO MANILA
ALOS PSR 1.5 2010-02-28 14-37-36.tif



SATELLITE IMAGERIES	DATE	AREA COVERAGE	EXTENT (degrees)				PROJECTION	DATUM	SPATIAL RES
			N		E				meters
			TOP	BOTTOM	LEFT	RIGHT			
ALOS PALSAR	Feb-10	METRO MANILA	14.66488877	14.51855856	120.5272323	121.2692015	UTM, ZONE 51N	WGS-84	6.25

METRO MANILA
ALOS PSR 1.5 2010-06-29 14-34-22.tif



SATELLITE IMAGERIES	DATE	AREA COVERAGE	EXTENT (degrees)				PROJECTION	DATUM	SPATIAL RES
			N		E				meters
			TOP	BOTTOM	LEFT	RIGHT			
ALOS PALSAR	Jan-10	METRO MANILA	14.86441945	14.02028047	121.0606418	121.8062185	UTM, ZONE 51N	WGS-84	12.5

Fig. 5 ALOS PALSAR of Metro-Manila

Pre-Processing

- Mosaic

The following are mosaics of PALSARs and PRISMs, respectively:

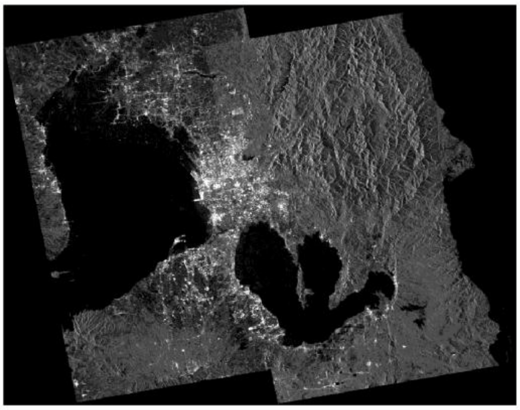


Fig. 6 PALSAR Mosaic of Metro-Manila

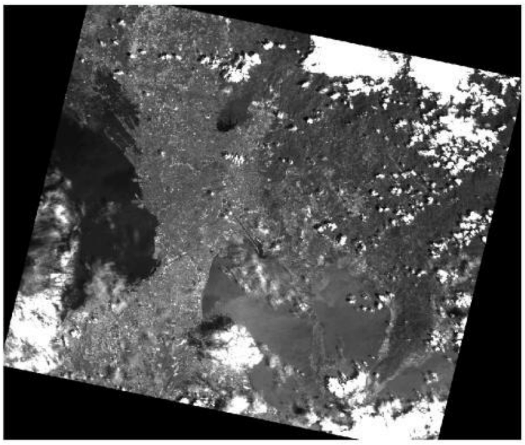


Fig. 7 PRISM Mosaic of Metro-Manila

- Subset

After mosaicking, similar subsets of PALSAR, PRISM and AVNIR-2 were obtained as shown below:

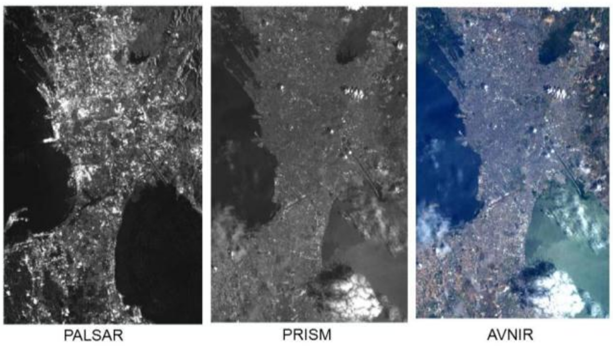


Fig. 8 ALOS PALSAR, PRISM and AVNIR-2 Subsets of Metro-Manila

- Resample

PALSAR and AVNIR-2 imageries were resampled to the resolution of PRISM at 2.5 m.

Enhancement

- Pansharpen (AV2 W/ PSM)

According to the webpage on the subject, GEOSAGE, "image fusion" are the terms used to describe the combination of severable images into a single product, by means of which greater information could be derived rather than what could be revealed from the individual input imageries. [5] GEOSAGE mentions further that a method for "image fusion" is called "pan-sharpening", which transforms a "set of coarse (low) spatial resolution multispectral (colour) images to fine (high) spatial resolution colour images, *by fusing* a co-georegistered fine spatial resolution panchromatic (black/white) image." [5]

Most of the time, for pansharpening, "blue, green and red" bands are applied "as main inputs in the process", thereby generating "a high-resolution natural (true) colour image." [5]

As a demonstration of image fusion for image enhancement purposes, AVNIR-2 imageries were pansharpened with PRISM. This was in order to better delineate urban land use/ cover features, as shown, for example below:

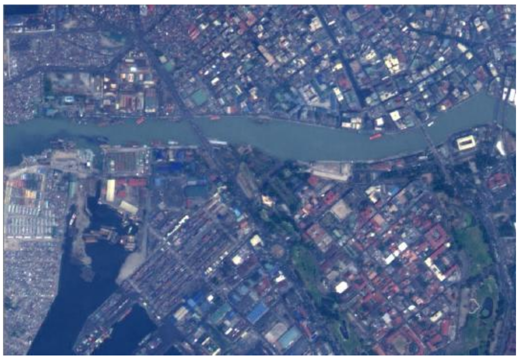


Fig. 9 AVNIR-2 Pansharpened with PRISM of Metro-Manila

- LEE Enhance Filter

For radar imageries:

> "A slightly simpler speckle filter is the [so-called] Lee Sigma Filter [6]. It… runs a sliding (usually square) window over the image and replaces the central pixel under the window by the average of the most likely pixels in the window. The pixels chosen to form the average are those lying within two standard deviations ("sigmas" and hence the

name of the filter) of the central pixel's value. Clearly, for a heterogeneous region fewer window pixels will lie within the two sigma range and less average will occur, whereas for homogeneous regions there will be a substantial averaging and thus speckle reduction." [7]

In the case of the study, the default window of 3 x 3 was applied.

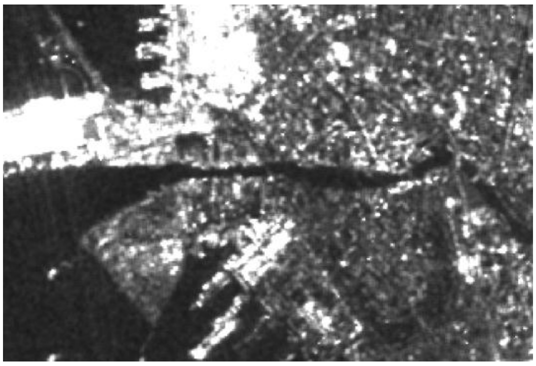


Fig. 10 Result of Lee Filter over PALSAR sub-scene of Metro-Manila

Image Processing: Slum Extraction

- Data Fusion (Pansharpened AV2 W/ PSR) – Brovey Transform

"Data fusion generally entails the combination of multi-sensor, multi-spatial, and multi-band imagery resulting in an enhanced composite image which is suitable for visual interpretation purposes. In addition, preserving as much as possible the spectral response of the original images ensures reliable results from the classification process [8].

There are several popular methods currently being used in data fusion. Most of them involve the manipulation of color space [8]…[such as]: The PCA-HIS-RGB, RGB-HIS-RGB, and the Brovey Transform… Of the three methods, the Brovey Transform [9], presented the least color enhancement but provided better discrimination of linear and edge features… The Brovey transform has been used commonly for merging passive multi-sensor (e.g. SPOT XS and SPOT Pan, and LANDSAT TM and SPOT) images…" [10]

For use with AVNIR-2s (multispectral), and PALSARs (radar), the Brovey Transform was automatically applied as follows (See Fig. 11):

"RED = B3 / (B1 + B2 + B3) * Radar Band
GREEN = B2 / (B1 + B2 + B3) * Radar Band
BLUE = B1 / (B1 + B2 + B3) * Radar Band" [10]

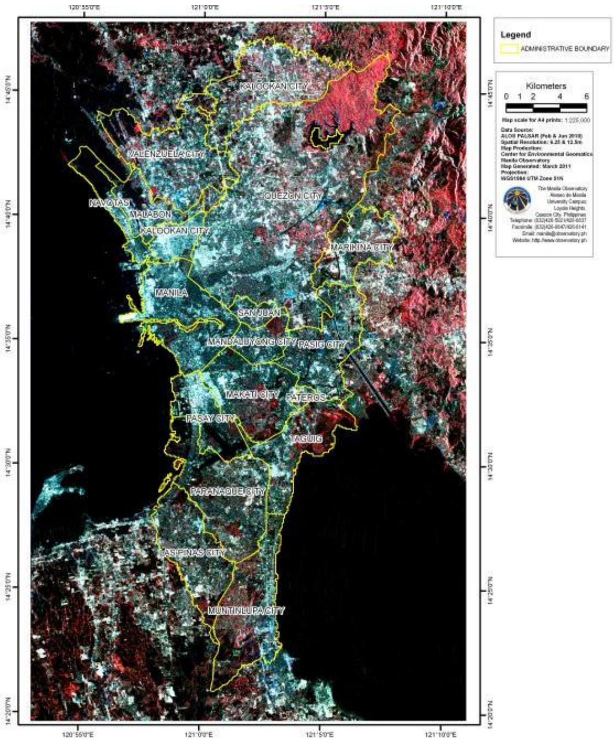


Fig. 11 Pansharpened AVNIR-2 with PALSAR – Brovey Transform

- Vegetation Delineation

The delineation of moderate and sparse vegetation (Fig. 12) was greatly aided by the previously transformed and fused imagery.

Fig. 12 Delineation of Vegetation

- Clustering

"[The] iterative self-organizing unsupervised classifier" called ISOCLUST, which is based on the "Maximum Likelihood procedure" [11], was then applied to the Brovey Transformed PALSARs and AVNIR. This is to generate differentiated land use/ cover features, especially footprints of slum areas or informal settlements (in shades of dark red). The results are still subject to ground verification and further refinement.

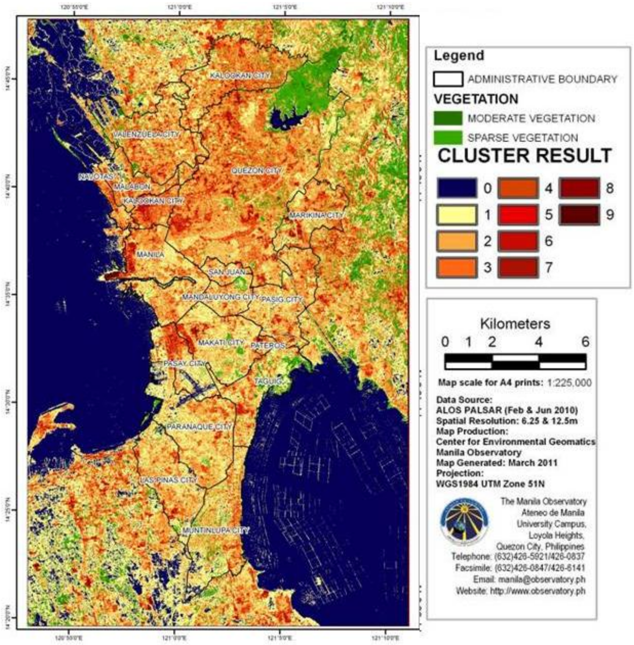


Fig. 13 ISOCLUST of Brovey Tranformed AVNIR-2 with PALSAR

Image Processing: Comparative Land Use Classification

For wider land use classification, the following Processes 1-3 were implemented. (See Fig.15) For filtering under Process 1 and 1.v1, the following 5 x 5 window was applied, which is based on "a restoration convolution filter which improves the sensor pdf response" [12]. The matrix coefficients are as follows:

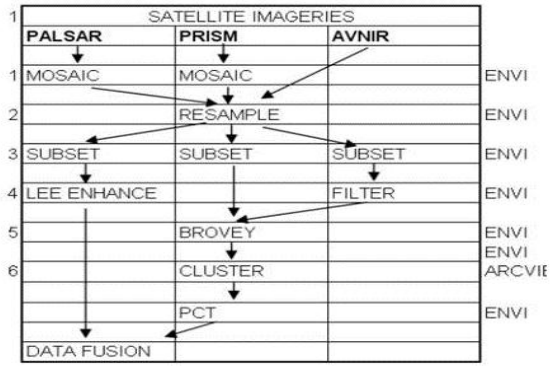
-0.0562	0	-0.4448	0	-0.0562
0	0	0	0	0
-0.4448	0	3	0	-0.4448
0	0	0	0	0
-0.0562	0	-0.4448	0	-0.0562

All processes feature data fusion/ pansharpening, such as through the Brovey Transform (Process 1, 1.v.1 and 3), using either processed PRISM or PALSAR. The image calculator was used, particularly in Process 2, in order to generate imageries that are transformed according to the Normalized Difference Vegetation Index (NDVI), Index of Brilliance (IB) and "Index of Sedimentation" (IS). [13, 14, 15, 16] (See Fid. 14) For image classification, unsupervised clustering (ISOCLUST) was applied in all Processes.

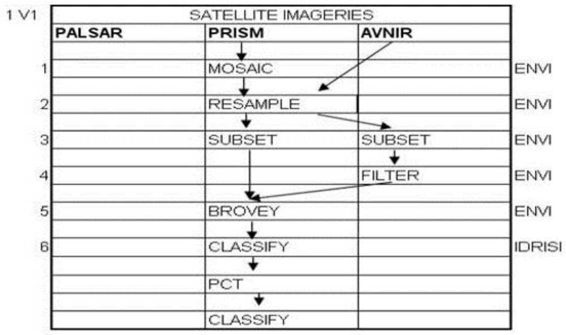
Fig. 15 (Right) Image Processes 1 to 3

SATELLITE IMAGERIES	SPOT XS		AVNIR-2	
ENERGY RANGE	Green	B1	Green	B1
	Red	B2	Red	B2
	NIR	B3	NIR	B3
NDVI	(B3-B2)/ (B3+B2)		(B3-B2)/ (B3+B2)	
IB	SQRT ($B2^2$ + $B3^2$)		SQRT ($B2^2$ + $B3^2$)	
IS	SQRT ($B1^2$ + $B2^2$)		SQRT ($B1^2$ + $B2^2$)	

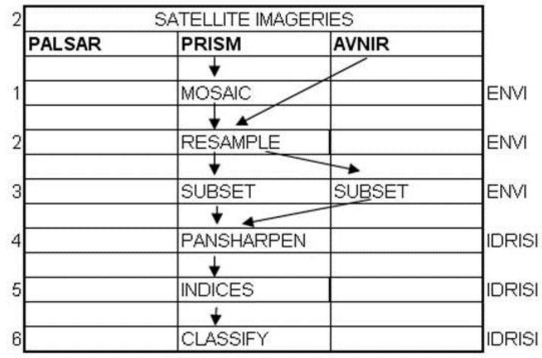
Fig. 14 Imaging Algorithms: NDVI, IB and "IS"



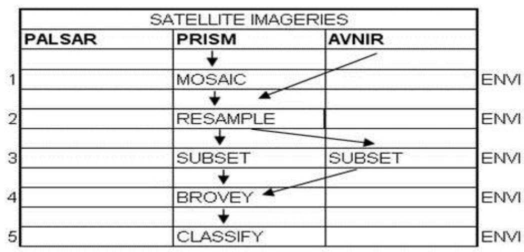
Process 1



Process 1.v.1



Process 2



Process 3

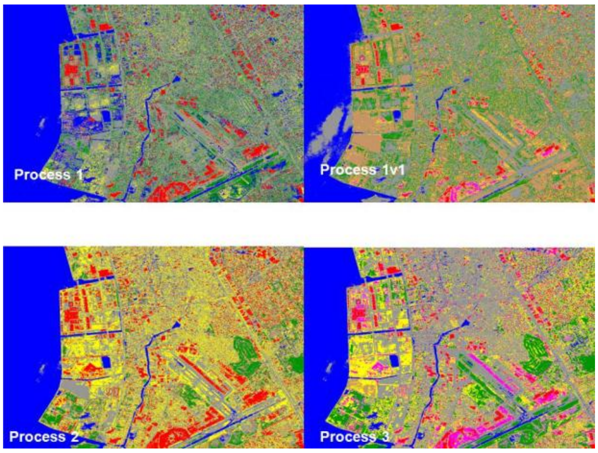


Fig. 16 Comparison of Results of Process 1, 1.v.1 (Upper left and right), 2 and 3 (Lower left and right)

Fig. 16 shows comparative results of Processes 1, 1.v1, 2 and 3. Process 1 demonstrates some confusion of land use/ cover with water bodies but it may be more useful in detecting slums or informal settlements, subject to ground verification. Process 1.v.1 reveals broader generalization of built-up areas. Process 2 enables the best generalization of large-scale urban features while Process 3 appears to generate the best differentiation of the same urban features.

GIS of Cross-Cutting Themes

The SPOT 5 XS true-color map below shows the overlay of 2000 aggregate informal settlements with Storm Ondoy Flooding of September 2009. This 2000 map of slum footprints is presently being updated using not only SPOT XSs and P but also AVNIR-2s, PRISMs and PALSARs. An estimated number of informal settlers affected by Storm Ondoy is given in Fig. 17.

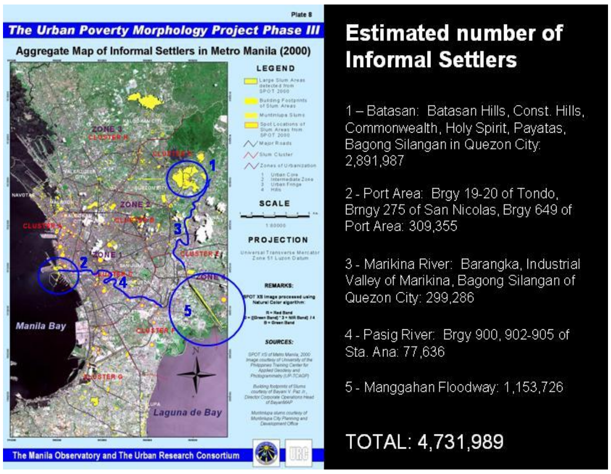


Fig. 17 Estimate of Informal Settlers Affected by Flooding due to Storm Ondoy

7. INTERIM RESULTS AND NEXT STEPS

RS-GIS-based land use/ cover classification represent exposure maps on the bases of which vulnerability mapping are to be undertaken. When these exposure and vulnerability maps are correlated with climate/ weather-related, geophysical and ecological hazards, integrated risk mapping are further enabled. The results are evidence-based decision support toward co-beneficial climate change adaptation and disaster risk management (CCA-DRM). Rural-urban complexities in terms of problems and solutions are, thus, better visualized, evaluated and monitored through the geospatial tools of RS-GIS.

Slum detection and wider land use classification using multi-date SPOT XS (1988, 1997, 2000 and 2008), AVNIR-2 (2010), PRISM (2010) and PALSAR (2010) are foreseen in the coming months, thereby enabling the comparison of urban complexities by type of ridge, river to reef rural-urban ecosystems. The next steps for Metro-Manila are groundtruthing or ground verification. Then contextual coverage with subsets of imageries of other pilot sites (i.e. Naga City, Cagayan de Oro City, Davao City and Zamboanga City) are to be taken for classification according to the previously mentioned processes. The hypothesis is that certain processes are better adapted to unique complexities of the ridge to reef rural-urban ecosystem.

Other tasks and ways forward are downscaling of historical and projected climate scenarios as well as mapping of associated geophysical and ecological hazards. A major activity based on resulting Hazard, Exposure, Vulnerability and Risk (HEVR) maps is the development of the rural-urban land use evaluation system in terms of adaptiveness to climate and disaster resilience. The various combinations of optional CCA-DRM strategies are to be weighed against non-intervention via the appropriate cost-benefit analyses. Regional risk digests and profiles shall be collated in the form of a Project Case Work (PCW) toolkit. These PCWs are to be satellite-based risk communication products and development instruments in as much as these are also governance tools.

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11. THE PROJECT TEAM

May Celine T.M. Vicente[1], Gemma T. Narisma[1], Flordeliza P. del Castillo[1], Emmi Capili-Tarroja[1], Emir V. Epino[7], Charlotte Kendra Z. Gotangco[1], Nofel C. Lagrosas[1], Dexter S. Lo[5], Ma. Antonia Y. Loyzaga[1], Daniel J. McNamara, SJ[1], Rosa T. Perez[1], Ermelina G. Regis[4], Mario S. Rodriguez[7], Lourdes R. Simpol[6], Fernando P. Siringan[2], Quirino M. Sugon, Jr.[1], Doracie B. Zoleta-Nantes[3]

[1] Manila Observatory, [2] University of the Philippines Marine Science Institute, [3] Australian National University, [4] Ateneo de Naga University, [5] Xavier University, [6] Ateneo de Davao University, [7] Ateneo de Zamboanga University