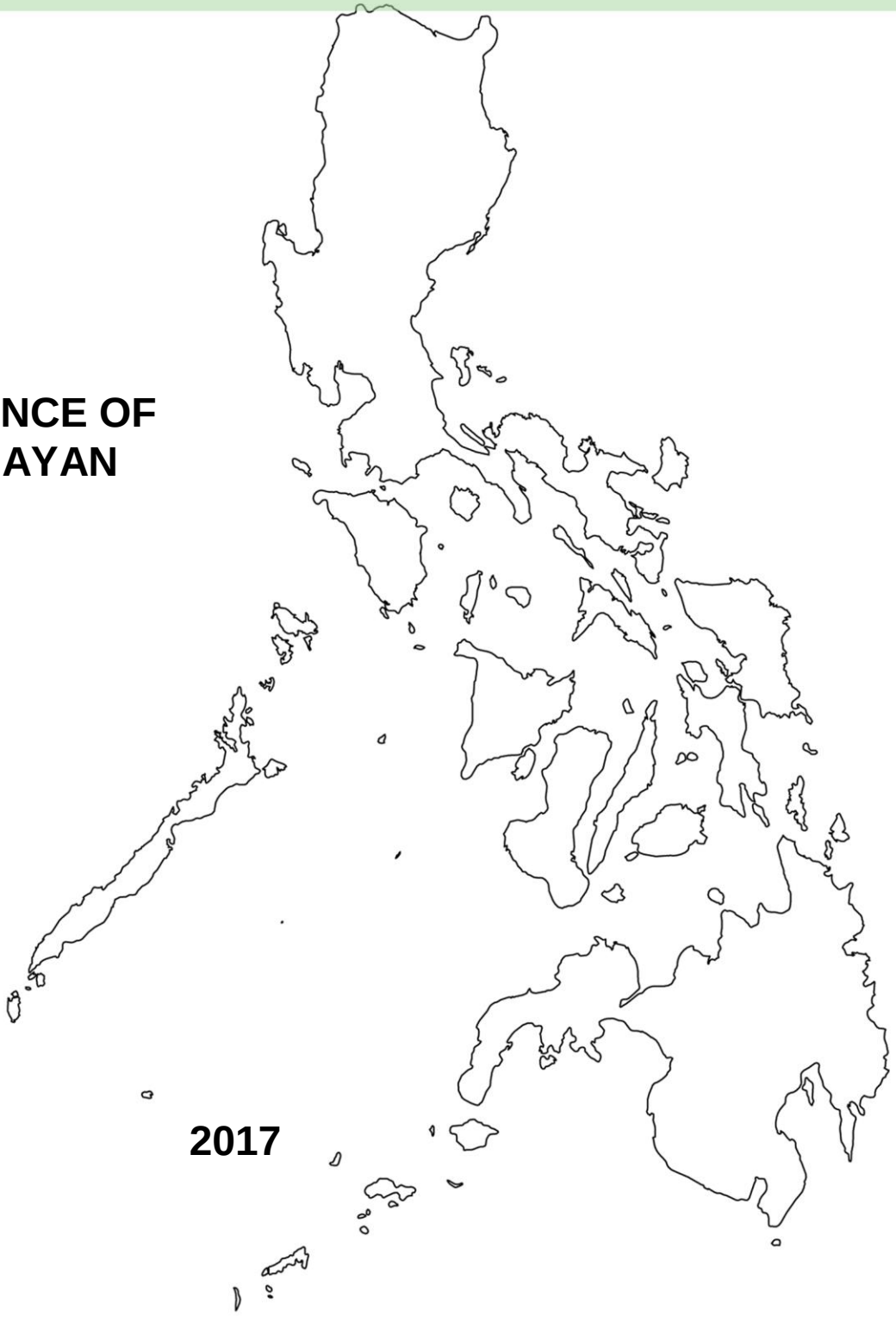
DEPARTMENT OF AGRICULTURE
Bureau of Soils and Water Management

Agricultural Land Management and Evaluation Division

National Mapping, Characterization and Development of Spatial Database for the Coastal Areas Affected by Salinity



PROVINCE OF CAGAYAN

2017

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RATIONALE

Salinity is long time known as one of the problem soils. It directly affects the agriculture and fishery sector in terms of productivity and income. Seriously salt-affected soils result to a total crop failure. The reasons for salinity are 1) increasing trend in sea level rise, 2) over pumping of the aquifers, and 3) seepage along the river — that is, when seawater moves upstream into the river during periods of high tide and low river flow.

The Bureau of Soils and Water Management (BSWM) have initiated several studies regarding soil salinity, but a nationwide information system has never been developed for areas affected by salinity. A baseline information on salinity will be a significant input in infrastructure planning in agriculture and fishery, risk management — particularly disaster risk management and climate change adaptation, — and policy recommendations.

Based on BSWM Reconnaissance Survey in 1988, forty five (45) provinces are identified affected by salinity. They represent more than half of the country's provinces. However, the extent of this condition to Philippine soils is not yet established and thus the subject of this project.

This project generally aims to develop a national information system for the coastal areas affected by salinity. Specifically, it aims to:

1. describe the soil physico-chemical characteristics;
2. generate salinity maps;
3. develop spatial database on salinity for the coastal areas;
4. undertake suitability evaluation for agriculture and fisheries and prepare scenarios as input to policy.

CAGAYAN

I. Soil Physical Characteristics

A. General Description of the Site

Cagayan is part of the largest valleys in the Philippines, formed by the majestic Sierra Madre and Cordillera mountain ranges. It lies in the northeastern part of mainland Luzon, approximately $17^0$30' North and $121^0$15' East, occupying the lower basin of the 330-km long Cagayan River and its Capital - Tuguegarao City, which is approximately 483 km north of Manila.

There are thirteen (13) coastal municipalities and one hundred three (103) barangays susceptible to salinity, hence the sites for soil sampling are as follows:

Table 1.1 Coastal Areas and Municipalities on the Lower Cagayan River Basin

No.	MUNICIPALITY	No. of Brgys.	No. of Sampling Sites	No. of Soil Samples Collected
1	Abulug	9	11	33
2	Ballesteros	7	10	30
3	Buguey	13	13	39
4	Camalaniugan	7	7	21
5	Sta. Ana	8	23	69
6	Gonzaga	8	11	33
7	Sta. Teresita	6	6	18
8	Claveria	6	9	27
9	Aparri	19	19	57
10	Lal-lo	1	1	3
11	Sanchez Mira	7	7	21
12	Pamplona	8	9	27
13	Allacapan	4	4	12
	TOTAL	**103**	**130**	**390**

B. Land Management Unit (LMU)

Land Management Unit is a recurring pattern of land which possesses similar physical characteristics such as soil type associated with relatively uniform land use or vegetation cover and parent material. It is the building block of the pedo -ecological zone, which represents a broader landscape grouping such as lowland, upland, hillyland and highland.

There are five Land Management Units, where due to its physiography are affected by salinity. These are the following:

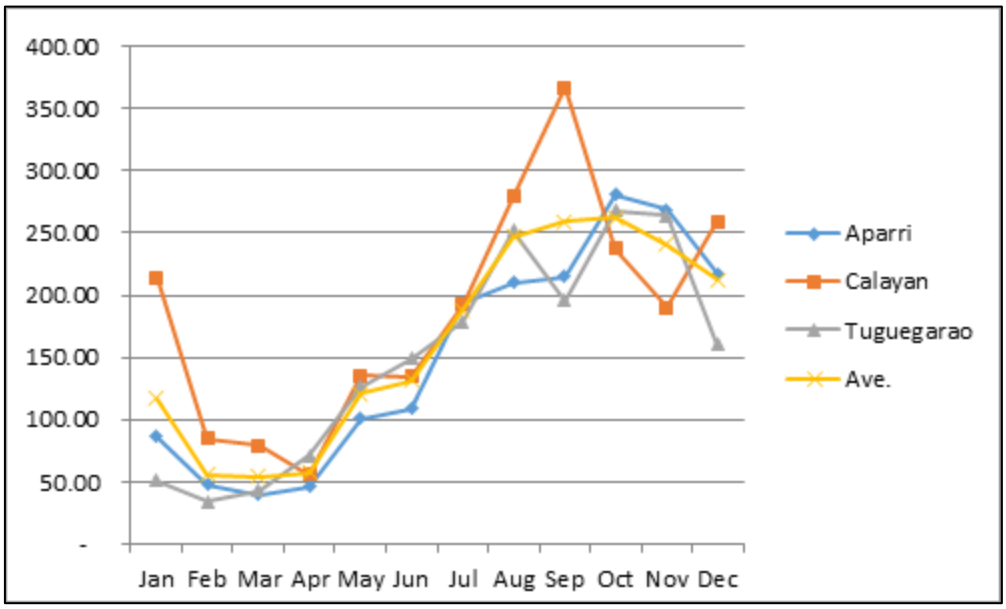
1. LMU 01 - Active Tidal Flats (Developed Fishpond)
2. LMU 02 - Mangrove
3. LMU 08 - Beach, Ridges and Swales
4. LMU 09 - Broad Alluvial Plain
5. LMU 16 - Infilled Valley

C. Elevation

The elevation of a geographic location is the height above sea level (meters above sea level). Soil sampling points are taken from the following elevation that ranges from 0-5 masl, 5-10 masl and 10-15 masl. In some cases however, soil sampling go beyond 15 masl (15-20 masl and 20-25 masl) depending on the suspected saline water intrusion in the area.

D. Agro-Climate

Figure 1.1 Rainfall Pattern, Province of Cagayan



Source: PAGASA – Aparri, Calayan, and Tuguegarao

During dry months surface accumulation of salts increases in saline affected areas. On the other hand, during rainy months salts start to leach into lower depths. Dry months in Cagayan Province are February to June, while rainy months are July to December. In this project, soil sampling was done during the dry months of April to May 2017 to determine the extent of salinity in the area.

According to the Modified Corona's Classification of Climate, Cagayan Province is in Type III Climate: No very pronounced maximum rain period, with a short dry season lasting only from one to three months, either during the period from December to February or from March to May. This climate type resembles type I since it has a short dry season.

E. Land Use

Land use involves the management and modification of natural environment. It also has been defined as "the total of arrangements, activities, and inputs that people undertake in a certain land cover type". Land use and vegetation plays an important role in the identification of areas affected by salinity. It provides indicative information primarily on the physical and socio-economic activities prevailing in the area. On the other hand, salinity reduces the kinds of crops that can be grown for economic purposes due to chemical reactions between salt water and soil clay particles.

The common land use/ vegetation in Cagayan sampling sites are presented in Table 1.2. Some indicators of salinity per municipality are also indicated in this table.

Table 1.2 Land use/ vegetation in Cagayan sampling sites.

Municipality	Land Use/ Vegetation	Some indicators of salinity
ABULUG	Paddy Rice, mangrove, Nipa, pasture	Nipa
BALLESTEROS	Paddy Rice	white color of soi, low yield, dying plants, yellowish and reddish leaves
BUGUEY	Paddy Rice	dying and delayed growth of plants
CAMALANIUGAN	Irrigated Paddy Rice	decrease in yield
STA. ANA	Paddy Rice, mangrove, Nipa	Nipa, salt like residue in soil
STA. TERESITA	Paddy Rice	salt like residue in soil
CLAVERIA	Paddy Rice, pasture	dying of weeds
LALLO	corn, vegetables	empty panicle, stunted growth
SANCHEZ MIRA	Paddy Rice, corn	white color of soil,dying plants, salt like granules on soil, dying of snails
APARRI	Paddy Rice	salt like residues on the soil
GONZAGA	Paddy Rice	salt residue on the soil, withered plants
ALLACAPAN	Non-Irrigated Paddy Rice	white color of soil, dying water lilies and snail
PAMPLONA	Paddy Rice, corn	dying plants, reddish leaves, empty panicle, stunted growth

II. Soil Chemical Characteristics

To test the salinity of the soil, samples are taken for laboratory analysis and the following are determined:

1. **Electrical Conductivity (EC)** – is a measurement of the dissolved material in an aqueous solution, which relates to the ability of the material to conduct electrical current through it. It is measured in Seimens per unit area (e.g. mS/cm)

2. **pH** is a measure of the acidity of the soil on its hydrogen ion concentration. The pH ranges on a logarithmic scale from 1-14, where pH 1-6 are acidic, pH 7 is neutral, and pH 8-14 are basic. Lower pH corresponds with higher [H^+], while higher pH is associated with lower [H^+].

3. **Sodium Adsorption Ratio (SAR)** – is a measure of the amount of sodium (Na) relative to calcium (Ca) and magnesium (Mg) in the water extract from saturated soil paste.

$$SAR = \frac{[Na^+]}{\sqrt{\frac{([Ca^{2+}]+[Mg^{2+}])}{2}}}$$

Soil water salinity can affect soil physical properties by causing fine particles to bind together into aggregates. This process is known as flocculation and is beneficial in terms of soil aeration, root penetration, and root growth. Although increasing soil solution salinity has a positive effect on soil aggregation and stabilization, at high levels salinity can have negative and potentially lethal effects on plants. As a result, salinity cannot be increased to maintain soil structure without considering potential impacts on plant health.

Sodium has the opposite effect of salinity on soils. The primary physical processes associated with high sodium concentrations are soil dispersion and clay platelet and aggregate swelling. The forces that bind clay particles together are disrupted when too many large sodium ions come between them. When this separation occurs, the clay particles expand, causing swelling and soil dispersion.

Soil dispersion causes clay particles to plug soil pores, resulting in reduced soil permeability. When soil is repeatedly wetted and dried and clay dispersion occurs, it then reforms and solidifies into almost cement-like soil with little or no structure. The three main problems caused by sodium-induced dispersion are reduced infiltration, reduced hydraulic conductivity, and surface crusting.

Salts that contribute to salinity, such as calcium and magnesium, do not have this effect because they are smaller and tend to cluster closer to clay particles. Calcium and magnesium will generally keep soil flocculated because they compete for the same spaces as sodium to bind to clay particles. Increased amounts of calcium and magnesium can reduce the amount of sodium-induced dispersion.

A. Salinity Classification

Table 2.1 Salinity Classification (Crop-based , Rice) (BSWM/FAO Salinity Project, 1999)

Electrical Conductivity (*mS/cm*)	Soil Salinity Class	Effect on Plants
0 - 2	Non Saline	Very little chance of injury on all plants.
2.1 - 4	Slightly Saline	Sensitive plants and seedlings may show injury
4.1 - 8	Moderately Saline	Most non-salt tolerant plants will show injury; salt-sensitive plants will show severe injury.
> 8	Severely Saline	Very few plants will tolerate and grow

The laboratory results for salinity testing of this project are classified using Table 2.1, based from the BSWM/FAO Salinity Project in 1999. This salinity classification is rice-based and applicable to Philippine setting.

Salinity maps (@ pages 11-13) are produced at three different depths: 0-30, 30-60 and 60-90cm. Tables 2.2 and 2.3 summarize the coastal land and rice area of Cagayan per degree of salinity. Based from these tables, saline areas are generally higher at 60-90cm depth at 0.34% and 1.37%. Further and in-depth analysis is discussed on the suitability assessment.

Table 2.2 Distribution of Coastal Land Area at Different Degree of Salinity, Cagayan

Salinity Class	Soil Depth					
	0-30cm		30-60cm		60-90cm	
	hectares	%	hectares	%	hectares	%
Non saline	328,365	92	321,444	90	309,118	87
Slightly saline	22,161	6	24,982	7	31,839	9
Moderately saline	4,820	1.1	8,549	2.4	13,858	4
Severely saline	899	0.3	1,269	0.4	1,430	0.4
TOTAL	356,245	100	356,245	100	356,245	100

Table 2.3 Distribution of Coastal Rice Areas at Different Degree of Salinity, Cagayan

Salinity Class	Soil Depth					
	0-30cm		30-60cm		60-90cm	
	hectares	%	hectares	%	hectares	%
Non saline	40,686	77	32,514	61	26,715	50
Slightly saline	10,649	20	16,388	31	15,053	28
Moderately saline	1,399	3	3,630	7	10,583	20
Severely saline	347	0.65	549	1.03	729	1.37
TOTAL	53,080	100	53,080	100	53,080	100

B. Suitability Assessment

The Rice Suitability Map is an overlay of the Salinity map (0-30cm depth) and the 2016 Rice Suitability Map for the coastal rice area.

The Rice Suitability Map of Cagayan (page 14), shows that the Highly Suitable (S1) area for rice is 0% of the total coastal area, while Moderately Suitable (S2) with varying limitations is 86.72% of the total coastal area. However, Marginally Suitable (S3) and Not Suitable (Nn) areas can be promoted to S2 if the limiting factors (listed in the suitability map) will be corrected.

C. Rice Yield by Degree of Salinity

Salinity problem affects water uptake of crops, slows down rate of growth and results to yield losses. Table 2.4 shows the percent decrease in average yield of farmers per degree of salinity. Based from the key informant interview and the results of the laboratory soil analysis, Table 2.4 shows that there is 33.3%, 50% and 58.3% decrease in yield on slightly, moderately and severely saline irrigated paddy rice, respectively. While for non-irrigated paddy rice, there is a 25% decrease in yield for slightly saline and 50% decrease in yield for moderately saline. This generally shows that as the degree of salinity increases, decrease in yield also increases.

The percent decrease in rice yield for the three sites are somewhat comparable to the rice yield loss result reported in the study entitled "The Effects of Salinity at Different Growth Stages on Rice Yield" by Rad, H.E., et al.

It is suggested however that further study on the seasonal and spatial variation of soil salinity be conducted to address the adverse effects of salinity to crops.

Table 2.4 Average Rice Yield by Degree of Salinity, Province of Cagayan, CY 2015-2016

Degree of Salinity	Average Yield Irrigated Paddy Rice (kg/ha)	% Decrease in Yield	Average Yield Non- Irrigated Paddy Rice (kg/ha)	% Decrease in Yield
Non saline	6,000		4,000	
Slightly saline	4,000	33.3	3,000	25
Moderately saline	3,000	50	2,000	50
Severely saline	2,500	58.3		

Table 2.5 Coastal Land Area (in hectares) per Municipality at Different Degree of Salinity
(Table for Salinity Map of Cagayan @ 0-30cm depth, page 11)

	Municipality	Non Saline	Slightly Saline	Moderately Saline	Severely Saline
1	ABULUG	16,053	204.04	3	
2	ALLACAPAN	30,680			
3	APARRI	19,785	6,950	1,894	35
4	BALLESTEROS	9,094	1,491	592	823
5	BUGUEY	11,794	3,079	1,536	41
6	CALAMANIUGAN	6,763	887		
7	CLAVERIA	18,864	617		
8	GONZAGA	56,508	162	72	
9	LAL-LO	69,800	480		
10	PAMPLONA	15,914	1,416		
11	SANCHEZ-MIRA	14,837	5,043		
12	SANTA ANA	41,904	1,616	610	
13	SANTA TERESITA	16,370	216	112	
	Grand Total	**328,365**	**22,161**	**4,820**	**899**

Table 2.6 Coastal Land Area (in hectares) per Municipality at Different Degree of Salinity
(Table for Salinity Map of Cagayan @ 30-60cm depth, page 12)

	Municipality	Non Saline	Slightly Saline	Moderately Saline	Severely Saline
1	ABULUG	15,584.82	425.39	248.36	1.43
2	ALLACAPAN	30,680.00			
3	APARRI	19,298.23	5,685.96	3,598.80	81.01
4	BALLESTEROS	9,165.77	1,407.79	605.23	821.20
5	BUGUEY	11,177.60	3,096.99	1,863.75	311.66
6	CAMALANIUGAN	6,395.36	1,254.64		
7	CLAVERIA	17,339.89	1,441.22	698.88	
8	GONZAGA	56,517.38	222.12	3.51	
9	LAL-LO	69,741.39	538.61		
10	PAMPLONA	14,197.98	1,956.12	1,122.27	53.64
11	SANCHEZ-MIRA	12,663.22	7,118.76	98.02	
12	SANTA ANA	42,365.53	1,562.36	201.72	0.38
13	SANTA TERESITA	16,316.88	272.25	108.86	
	Grand Total	**321,444.06**	**24,982.20**	**8,549.42**	**1,269.32**

Table 2.7 Coastal Land Area (in hectares) per Municipality at Different Degree of Salinity
(Table for Salinity Map of Cagayan @ 60-90cm depth, page 13

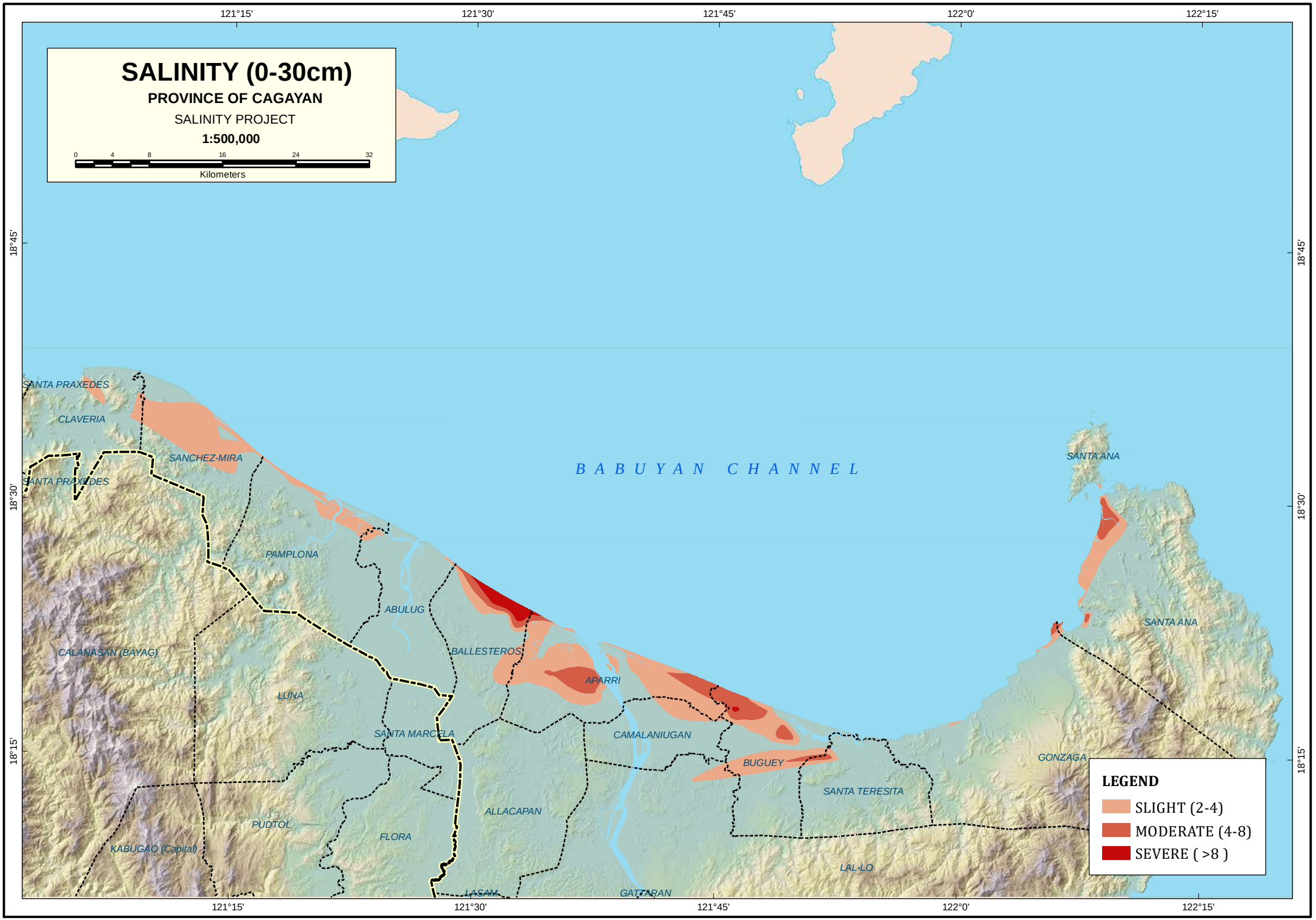
	Municipality	Non Saline	Slightly Saline	Moderately Saline	Severely Saline
1	ABULUG	15,444.90	519.34	158.14	137.62
2	ALLACAPAN	30,680.00			
3	APARRI	18,222.80	4,191.40	6,198.43	51.37
4	BALLESTEROS	6,900.49	2,950.07	1,273.96	875.48
5	BUGUEY	10,287.69	3,559.20	2,267.89	335.22
6	CAMALANIUGAN	6,039.49	1,587.44	23.08	
7	CLAVERIA	16,997.94	1,584.20	897.86	
8	GONZAGA	56,313.94	401.28	27.78	
9	LAL-LO	69,396.41	883.59		
10	PAMPLONA	11,500.11	4,356.87	1,442.25	30.78
11	SANCHEZ-MIRA	9,428.49	9,547.63	903.88	
12	SANTA ANA	42,067.58	1,551.93	510.49	
13	SANTA TERESITA	15,838.01	706.06	153.94	
	Grand Total	**309,117.85**	**31,838.99**	**13,857.69**	**1,430.46**

Table 2.8 Limiting Factors Ratings in Increasing Severity of Limitation
(Table for the Rice Suitability Map @page 14)

LIMITING FACTORS	RATING ARRANGED IN INCREASING SEVERITY OF LIMITATION			
	Highly Suitable (S1)	Moderately Suitable (S2)	Marginally Suitable (S3)	Not Suitable (N)
Water Availability				
m- No. of dry months (<75mm)	0-3	6-Apr	9-Jul	>9
r- Annual ave. rainfall(mm)	>1500	1200-1500	800-1200	<800
Temperature Regime				
t- Annual average temp (^{0}C)	25-29	30-32 22-24	33-35 18-21	>35 <18
Terrain				
s- Slope (%)	0-3	8-Mar	18-Aug	>18
o- Stoniness	None	Slight	Moderate	Severe
e- Erosion	None	Moderate	Severe	
i- Flooding	None	Moderate	Severe	
Rooting Condtions				
d- Soil drainage class	VPD-SPD	SPD-MWD	WD	SED-ED
x- Soil texture	C, SC, SiC; CL, SCL, SiCL	L, SiL, Si	SL, LS	S
h- Soil depth (cm)	>50	41-50	20-40	<20
Nutrient Availability				
f- Soil fertility	High-MH	ML	Low	-
Degree of Salinity				
n- Soil salinity (0-30 cm)	None	Slight	Moderate	Severe

Table 2.9 Legend for the Rice Suitability Map @ page 14
Coastal Rice Area - Province of Cagayan

LEGEND						
SUITABILITY RATING	DESCRIPTION	LIMITING FACTORS			AREA	
		Moderate	Marginal	Severe	ha	%
S2df	Moderately Suitable	d,f			7408	13.13
S2dfn		d,f,n			2577	4.57
S2dxf		d,x,f			966	1.71
S2dxfn		d,x,f,n			806	1.43
S2f		f			11531	20.44
S2fn		f,n			2314	4.10
S2idf		i,d,f			5351	9.49
S2idfn		i,d,f,n			1315	2.33
S2idxf		i,d,x,f			1869	3.31
S2idxfn		i,d,x,f,n			183	0.32
S2if		i,f			7170	12.71
S2ifn		i,f,n			1175	2.08
S2ix		i,x			173	0.31
S2ixf		i,x,f			2991	5.30
S2xf		x,f			2796	4.96
S2xfn		x,f,n			205	0.36
S3dx	Marginally Suitable	f	d,x		547	0.97
S3dx		f,n	d,x		219	0.39
S3dx		i,f	d,x		627	1.11
S3dx		i,f,n	d,x		228	0.40
S3dxn		f	d,x,n		159	0.28
S3dxn		i,f	d,x,n		32	0.06
S3f		i	f		326	0.58
S3f		i,n	f		79	0.14
S3f		i,d	f		17	0.03
S3n		f	n		624	1.11
S3n		x,f	n		63	0.11
S3n		d,f	n		593	1.05
S3n		i,f	n		462	0.82
S3n		i,d,f	n		98	0.17
S3x		d,f	x		300	0.53
S3x		i,d,f	x		2041	3.62
S3x		i,d,f,n	x		615	1.09
Nn	Not Suitable	f		n	16	0.03
Nn		d,f		n	13	0.02
Nn		f	d,x	n	123	0.22
Nn		i,f		n	122	0.22
Nn		i,f	d,x	n	271	0.48
TOTAL					**56,405**	**100.00**


SALINITY (0-30cm)
PROVINCE OF CAGAYAN
SALINITY PROJECT
1:500,000
0 4 8 16 24 32
Kilometers
121°15'
121°30'
121°45'
122°0'
122°15'
18°45'
18°30'
18°15'
B A B U Y A N C H A N N E L
SANTA PRAXEDES
CLAVERIA
SANCHEZ-MIRA
SANTA PRAXEDES
PAMPLONA
ABULUG
BALLESTEROS
APARRI
CALANASAN (BAYAG)
LUNA
SANTA MARCELA
CAMALANIUGAN
BUGUEY
SANTA ANA
SANTA ANA
GONZAGA
SANTA TERESITA
ALLACAPAN
PUDTOL
FLORA
KABUGAO (Capital)
LAL-LO
LASAM
GATTARAN
LEGEND
SLIGHT (2-4)
MODERATE (4-8)
SEVERE (>8)

SALINITY (30-60cm)

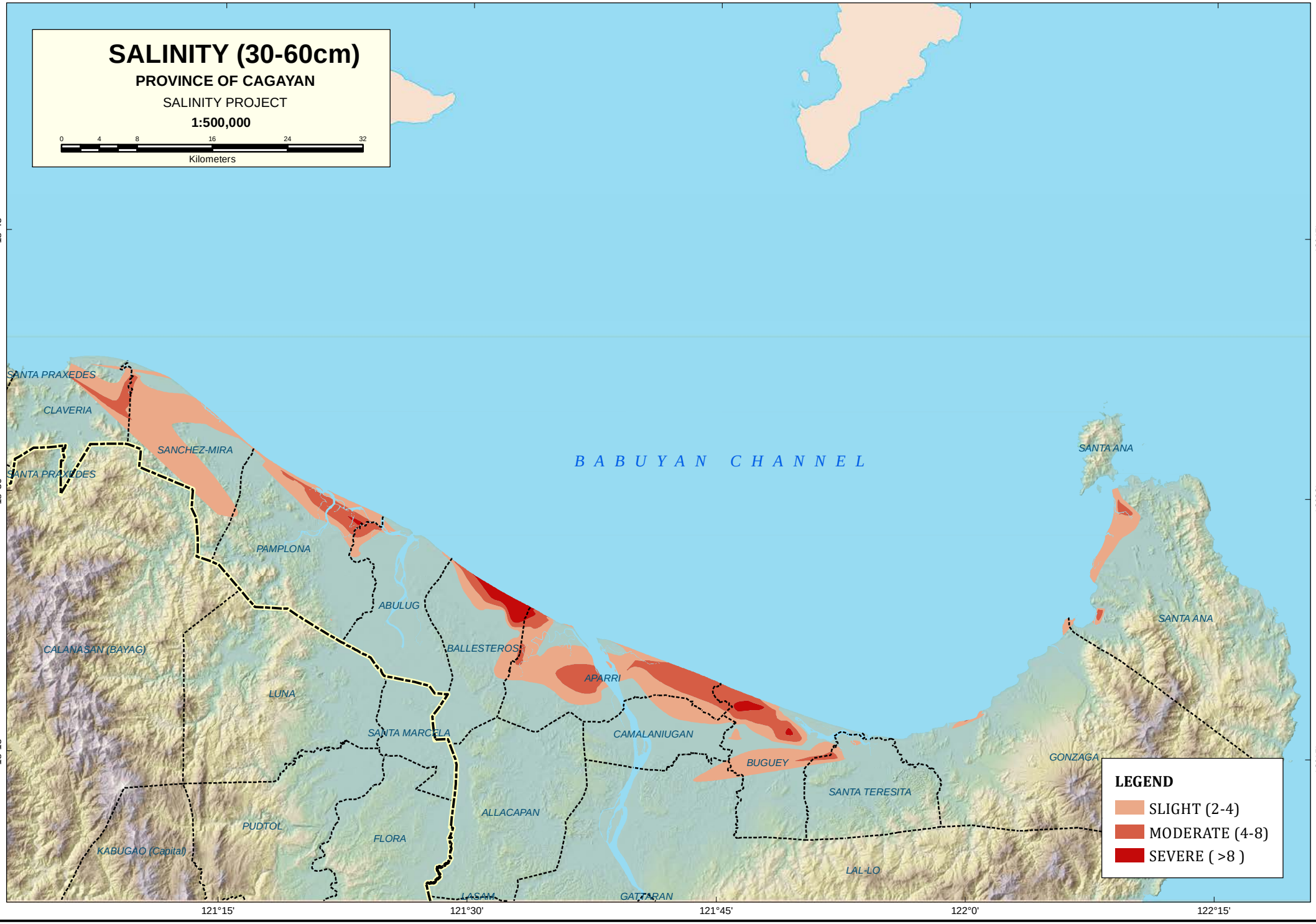
PROVINCE OF CAGAYAN

SALINITY PROJECT

1:500,000

0 4 8 16 24 32

Kilometers



SALINITY (60-90cm)

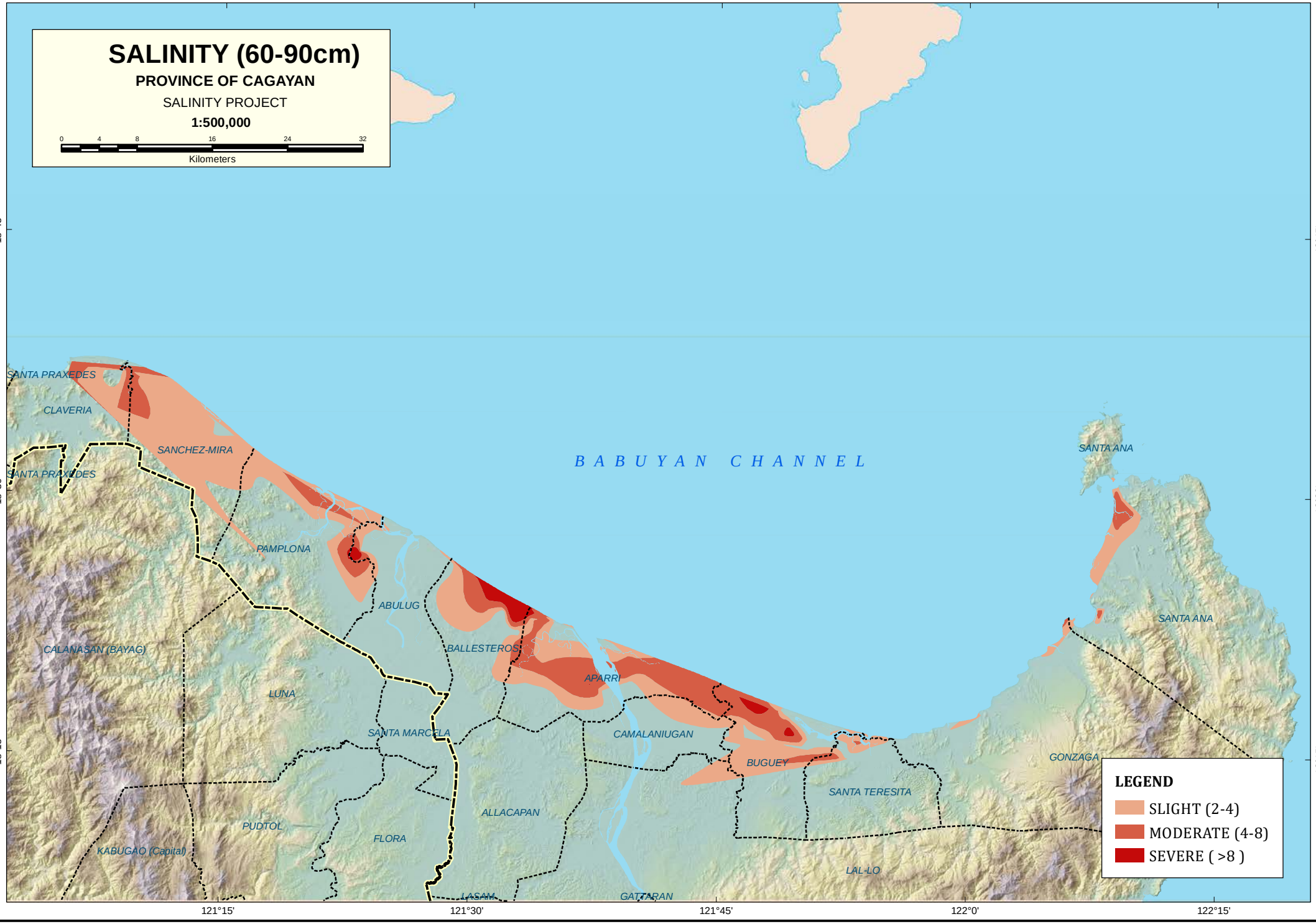
PROVINCE OF CAGAYAN

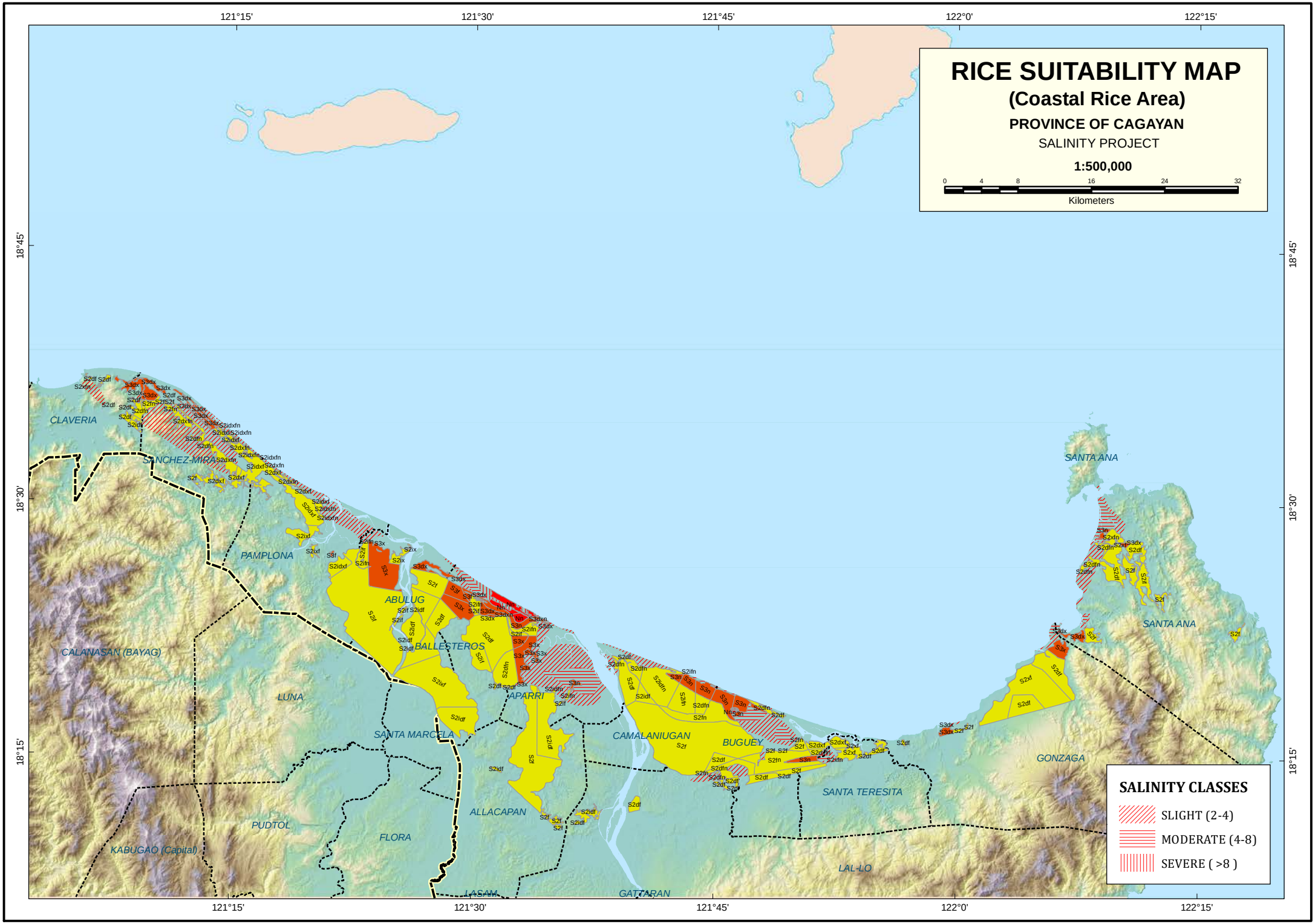
SALINITY PROJECT

1:500,000

0 4 8 16 24 32

Kilometers




RICE SUITABILITY MAP
(Coastal Rice Area)
PROVINCE OF CAGAYAN
SALINITY PROJECT
1:500,000
0 4 8 16 24 32
Kilometers
121°15'
121°30'
121°45'
122°0'
122°15'
18°45'
18°30'
18°15'
CLAVERIA
SANCHEZ-MIRA
PAMPLONA
ABULUG
BALLESTEROS
APARRI
CALANASAN (BAYAG)
LUNA
SANTA MARCELA
CAMALANIUGAN
BUGUEY
SANTA ANA
GONZAGA
SANTA TERESITA
PUDTOL
FLORA
ALLACAPAN
KABUGAO (Capital)
LAL-LO
GATTARAN
LASAM
SALINITY CLASSES
SLIGHT (2-4)
MODERATE (4-8)
SEVERE (>8)

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National Mapping, Characterization, and Development of Spatial Database for the Coastal Areas Affected by Salinity (2017)

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Auger Boring and Soil Sampling

Key Informant Interview