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Soil constraints and management options for rice production areas in Cagayan, Philippines

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Abstract

This study was conducted to develop soil constraints and management options for rice areas in Cagayan province, Philippines. Soil samples were taken from sixteen rice production municipalities in the province. Morphological properties of soils were investigated *in situ*. Samples were analyzed for their chemical and physical properties. Thirteen soil types were identified as Sta Rita clay loam, Toran silt clay, Isabela clay, Bantay clay loam, Buguey loamy sand, Quingua clay loam, San Manuel silt loam, Carig clay loam, Buguey sand, Alaminos silt clay, San Fernando clay, Toran loam, Quingua silt loam. Crop suitability analysis of these soils was done based on the soil characteristics studied per series and known requirements of each crop. Production constraints were identified and management practices recommendations were provided based on the recognized problems per soils series.

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Introduction

Knowledge of specific soil properties under various agricultural land use scenarios is necessary in making sound decisions regarding land use. The major areas planted to major crops (agricultural land use) in the province play an important role in food sustainability especially the major rice production areas. Moreover, dynamic soil properties are sensitive to land management practices and thus can provide valuable information about important soil processes and overall productivity potential.

SCAMP or Soil Constraints and Management Package (SCAMP) is a decision-support framework that attempts to bridge the gap between taxonomic soil surveys and informed management strategies for sustainable production on upland soils in the tropics. Being simple, yet comprehensive, it can be applied to any upland situation. The idea of the SCAMP is very useful thus this study wants to develop a similar framework for other rice ecosystems (rainfed and irrigated lowland) not only for upland that is specific for Cagayan.

Specifically, it aimed to; identify the major rice production areas and validate the spatial distribution of these areas in the province of Cagayan, characterize the soil planted to and/or utilized for rice production, analyze suitability of crop to different soil series characterized in the province, and identify production constraints and provide management practices recommendation based on the recognized problems.

Materials and methods

Identification of major areas utilized for rice production

Coordination meetings with LGUs and SUCs were conducted to identify the major areas planted to rice. Spatial distribution of rice areas in the province was identified based on the existing maps and data from LGU and these areas were validated during the soil reconnaissance survey. Preliminary data on production yield were gathered as baseline information for management recommendations.

Reconnaissance survey and site characterization (field observation)

Validation of selected major areas was done through reconnaissance survey. Pits were dug from each identified soil series and soil profiles were described *in situ*. Characteristics of the topsoil (plow layer) (0-20cm) and subsoil (20-50cm): texture, colour, structure, moist consistence, compaction and gravel rating were observed and the site information was recorded. Permeability class, drainage class and erosion hazard were recorded from site and mini-pit observations.

Soil sampling

From the identified major rice crop production areas in the province, approximately 3kg of soil were collected for laboratory analyses. Samples were taken based on horizon per soil profile.

Laboratory analyses

Soil samples from each sampling site were analyzed at the Analytical Services Laboratory (ASL) of Soils and Agro-Ecosystems Division, Agricultural Systems Cluster, College of Agriculture, UPLB. The following characteristics were determined; a. chemical - organic carbon and organic matter, pH (H_2O and $CaCl_2$ methods), exchangeable bases (K, Na, Ca, Mg) effective cation exchange capacity ($cmol_c \cdot kg^{-1}$), b. physical – texture.

Suitability analysis of rice to different soil types/series

Matching of the crop requirements and land/soil characteristics was done to determine the suitability of crop to the different soil series identified.

Identification of production constraints and development of SCAMP

Using the results of the suitability analysis, production constraints were identified. Limitations were determined and management options/practices were recommended to improve land use and maintain fertility status of the soil.

Results and discussion

Cagayan soils

The soils of the province are divided into three general groups namely: soils of the plains and valleys,

soils of the hills and mountains, and miscellaneous land types. Soils of the plains and undulating areas are of alluvial deposits and they comprise the most productive agricultural areas of the province. The major rice production areas/municipalities in the province were identified based on their soil types. The representative pedons were identified as Sta Rita clay loam *(Typic Epiaqualf)*, Toran silt clay *(Vertic Tropaquent)*, Isabela clay (*Vertic Tropaquept)*, Bantay clay loam (*Typic Eutrustept*), Buguey loamy sand (*Typic Ustipsamment*), San Manuel silt loam (*Fluventic Eutrudept*), Carig clay loam (Typic Eutrustept), Buguey sand, Alaminos silt clay (*Typic Kanhaplustult*), San Fernando clay (*Ustic Endoaquert*), Toran loam and Quingua silt loam (*Typic Epiaqualf*). Sixteen municipalities that were selected falls under ten (10) soil series as mentioned. The extent of these series is shown in Fig. 1.

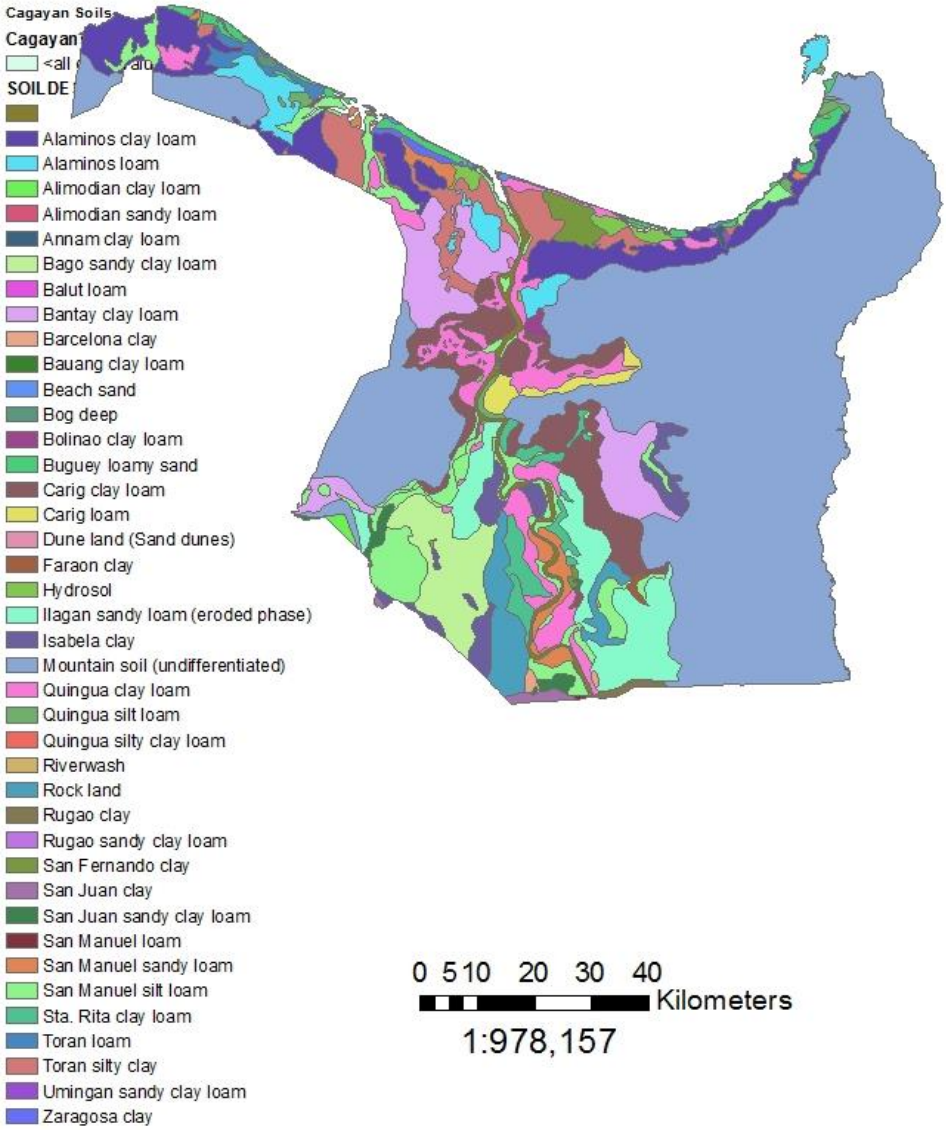

Fig. 1. Soil Map of Cagayan Province.

Cagayan geology and physiography

The basic determinant for land use allocation in the province is its physiography. The geologic formations in Cagayan according to the Geologic Survey of the U.S Army are as follows: alluvium – terrace flood plain, deltaic and littoral deposits, tuffaceous sediments–rocks and coralline locally, Pliocene sediments – mostly poor consolidated sandstone, silt, clay, and marl all more or less tuffaceous, Obligocene-Miocene sediments–predominantly elastic sandstone,

conglomerate, silt, and shale; tuffaceous in many places mush limestone particularly in the eastern part.

The eastern coast of the province is hilly and mountainous. The northern coast bordering China Sea is low; the southern portion bordering Kalinga is hilly while the area adjacent to Apayao is low and swampy. The northern coast has been largely valleys of alluvial soils deposited by rivers and from the surrounding hills and mountains.

Cagayan is well traversed by many rivers, the largest being Cagayan and Abulug. The former is 200 to 900 yards wide and about 300 kilometers long, flowing almost due north originating from the province of Nueva Vizcaya. It has two large tributaries, the Chico and Magat Rivers which drain practically the extensive Cagayan Valley Provinces. The Chico meanders in wide sweeps through the grasslands, tobacco fields, and forest lands of Cagayan.

Current land use of the selected soil types in Cagayan

The current associated land use for each soil series/types are presented in Table 1. The currently grown crops in the province are rice, coconut, corn, banana, tobacco, and legumes which are planted to level to nearly level areas. Fruit trees, pasture and forest trees are dominating areas with hilly to mountainous relief.

Soil properties of the selected soil series that affects crop growth

Based on the morphological characterization *in situ* and physico-chemical analysis of the samples, the results are shown in Table 2. The data that were presented are those factors or properties that are generally known to affect crop growth and development which are topography (measured by its slope), wetness (drainage and flooding), physical properties (texture, coarse fragments and effective rooting depth) and soil fertility which are measured thru presence of carbonates ($CaCO_3$), pH, CEC, base saturation and organic carbon percentages. Seasonal flooding is recorded for Isabela, Quingua and Toran soil series.

Table 1. Soil types and their existing associated land use in selected municipalities in Cagayan, Philippines.

Soils of the plains and undulating areas		
Soil type	Municipality	Land Use
Buguey loamy sand	Buguey, Sanchez Mira	rice, coconut, tobacco, corn and cotton
Buguey sand	Gonzaga	rice, coconut, tobacco
Isabela clay	Amulung	rice and vegetables
Quingua clay loam	Claveria	lowland rice and corn
Quingua silt loam	Sta. Teresita	lowland rice, corn
San Fernando clay	Solana	lowland rice,
San Manuel silt loam	Enrile, Tuao	corn, tobacco, peanut, rice and vegetables
Sta. Rita clay loam	Alcala	rice, corn, tobacco and peanut
Toran loam	Sta. Praxedes	rice
Toran silt clay	Allacapan	lowland rice, fruit trees
Soils of the rolling and hilly to mountainous areas		
Alaminos silt clay	Lallo	Upland rice, coconut, banana and root crops
Bantay clay loam	Rizal, Baggao	Upland rice, grassland, second growth forest
Carig clay loam	Gattaran	Upland rice

These series were found in Amulung, Claveria, Sta. Teresita, Sta. Praxedes and Allacapan municipalities. Effective rooting depth is deep (100cm) in almost all the series studied except for Alaminos (Lallo) and Bantay (Rizal and Baggao) with moderately deep (70cm) rooting depth. Presence of carbonates is noted in Quingua (Claveria and Sta. Teresita) and Sta. Rita (Alcala) series. pH ranged from 5.04 to 8.3. In terms of soil fertility, Isabela (Amulung), Quingua (Claveria and Sta. Teresita), Toran (Sta. Praxedes and Allacapan) and Carig (Gattaran) series were identified as fertile.

Good and limiting quality of selected soils in Cagayan

Based on the soil properties mentioned above, the good and limiting quality of the selected soils in Cagayan is summarized in Table 3. In general, the topography of the province is level to nearly level. These areas have moderately to highly fertile soils. They are also deep and formed through alluvial deposits. These soils can be agriculturally productive to different crops. San Manuel, and other alluvial soils are suitable for most crops grown in the province. Climatic conditions in the province are generally suitable for most crops being grown.

The shallow rooting depth, steep slope and low fertility of upland soils limit the production of upland crops. Grasses, shrubs and forest are the main vegetation of these areas. Most soils, particularly alluvial soils are clayey in texture. This limits the production of certain crops (e.g. corn, cassava) for diversification. Climatic factors such as rainfall, number of dry and wet months and relative humidity hinders the production of other potential crops in the area. Crops such as cabbage and other highland vegetables need modified environment that may not be cost-efficient.

Table 2. Soil properties of the different soils in Cagayan province that affects crop growth.

Soil Series	Topography (t)	Wetness (w)		Soil Physical Characteristics (s)				Soil Fertility (f)				
	Slope (%)	Drainage	Flooding	Texture	Coarse Fragment	Effective Rooting depth (cm)	% $CaCO_3$	pH (1:1) water	CEC (cmol/kg soil)	% BS	Sum of Basic Cations (cmol/kg soil)	Fertility (%OC)
Buguey	0-3	well drained	none	LS, S	none	deep (100)	-	5.6-6.1	10-11.2	16-29	1.5-52	0.09-0.10
Isabela	0-3	Poorly drained	seasonal	C	none	deep (100)	-	6.9-7.3	62.9-68.5	88-90	55.4-61.5	0.28-1.88
Quingua	3.0-7.0	well drained	seasonal	SL	gravels	deep (100)	2.0	5.8-6.7	15.9	52.9	8.39	
San Fernando	3.0-7.0	Poorly drained	none	C	none	deep (150)	-	5.9-8.0	29.7-41.3	68-90	20.2-33.6	0.15-0.97
San Manuel	0-3	well drained	none	SL, L	none	deep (100)	-	6.9-8.3	44-54.7	91-94	40-50.3	0.36-0.56
Sta. Rita	0-3	poor to poorly drained	none	CL	none	deep (150)	3.1-7.2	6.6-7.3	52.6-59.2	74-85	44-52.4	0.25-1.46
Toran	0-3.0	Poorly drained	seasonal	SiC	none	Deep (150)	-	5.04-5.23	37.7	77	38.4-40.5	0.14
Alaminos	7.0-20.0	Moderately drained	None	SiC	none	Moderately deep (70)	-	5.21-5.27	19.8	9	7.5-11.1	0.14
Bantay	7.0-20.0	excessively drained		CL	none	moderately deep (90)	-	5.24	46.3-52.1	71	44.2-47.2	0.15-0.17
Carig	7.0-20.0	Poor to poorly drained		CL	none	Deep (150)	-	5.8	20.4	48	16.8-59.6	0.12

Table 3. Good and limiting quality attributes of the selected soils in Cagayan.

Soil Series	Good Land Quality Attribute	Limiting Land Quality Attribute
Buguey	low level relief, good drainage, deep soil	low fertility (OM), soil texture especially for sugarcane
Isabela	low level relief, deep and fertile soil	poor drainage
Quingua	low level relief, good drainage, deep and fertile soil	presence of coarse fragments
San Fernando	good drainage	sloping topography, low OM
San Manuel	good drainage, low level relief, deep and fertile	seasonal flooding
Sta. Rita	low level relief, good drainage	seasonal flooding, low fertility
Toran	low level relief, deep and fertile soil	relief (irrigated rice only); climatic limitation
Alaminos	low level relief, deep soil, good drainage	low fertility, drainage (tomato, cassava)
Bantay	good drainage	sloping topography, low OM
Carig	good drainage, fertile	shallow soil depth, sloping topography, limestone fragments

Suitability of crops to selected soil series in Cagayan

Table 4 presents the crop suitability evaluation of selected soils in Cagayan. The suitability ratings showed that most of the agriculturally productive areas are grown to rice, corn and other crops (i.e. coconut) and even those located in the flat uplands. Even areas with steep slopes are planted with these crops. The natural vegetation of areas with steep slopes is grasses and shrubs with some fruit trees. However, patches of rice and corn are found growing in these areas.

Production potential of crops grown is being impeded by the edaphic environment. Crops that should be grown in some of the area are not being utilized instead of growing crops that are not suitable.

Table 4. Crop suitability analysis of selected Cagayan soils.

Soil Series	Irrigated Rice	Corn	Upland Rice	Banana	Sugarcane	Coconut	Tobacco	Peanut	Cassava	Pineapple
Buguey	S3s	S3s	S3s	S3s	S3s	S1	S1	S2	S2	S2s
Isabela	S1	S3w	S3w	S3w	S3w	S3w	N2w	S3w	N1ws	S3w
Quingua	S1	S1	S1	S1	S1	S1	S2f	S2f	S2	S1
San Fernando	S1	N2w	N2w	N2w	N2w	N2w	S3w	N2w	S1	N2w
San Manuel	S2w	S1	S1	S1	S1	S1	N2w	S1	N2wt	S1
Sta. Rita	S1	S3w	S3w	S3w	S3w	S3w	S2sf	S3w	S1	S3w
Toran	S2f	N2w	N2w	N2w	N2w	N2w	N2w	N2w	S3w	N2w
Alaminos	N2t	N2t	N2t	N1tw	N2t	N2t	N2t	N2t	N2w	N2t
Bantay	N2t	N2t	N2t	S3t	N2t	N2t	N2t	N2t	N2t	N2t
Carig	N2t	N2t	N2t	N1tw	N2t	N2t	N2t	N2t	N2t	N2t

Suitability ratings	Limitations due to:
S1-Highly suitable	t-topography, slope
S2-Moderately suitable	w-drainage, flooding
S3-Marginally suitable	s-soil physical properties (texture, soil depth, coarse fragments)
N1-Currently not suitable	f-soil fertility
N2-Permanently not suitable	c-climate

Summary of the suitability of some crops to the selected soil series in Cagayan is presented in Table 5. Based from the suitability analysis, some areas are found to be planted with some crops which are moderately to marginally suitable, while some are potentially suitable for certain major crops.

The existing land uses are traditional (planted as conventional crops).

Recommended land use in the selected municipalities of Cagayan province

The recommended land uses (Table 6) consider all crops that suitable to the area and these can give greater production. To maximize the use of land, intercropping and cover cropping can be considered to maximize the use of land. Production alternatives such as single intercrop, a mixture of intercrops, multiple cropping, to crop-livestock systems can be done to increase income and production.

Table 5. Suitability of some crops to the selected soil series in Cagayan.

Soil Series	Municipality	Highly Suitable	Moderately Suitable
Buguey	Buguey, Gonzaga, Sanchez Mira	coconut, tobacco	peanut, cassava, mango, pineapple, citrus, sorghum, onion, watermelon, upland rice
Isabela	Amulung	lowland rice	watermelon, giant ipil-ipil, pasture, forestry, bamboo
Quingua	Claveria, Sta. Teresita	lowland rice, corn, upland rice, banana, sugarcane, coconut, tobacco, cassava, pineapple, mango, sorghum, watermelon	peanut, coffee, citrus, onion
San Fernando	Solana	lowland rice	
San Manuel	Enrile, Tuao	corn, upland rice, banana, sugarcane, coconut, cassava, pineapple, mango, sorghum, watermelon, peanut, onion	lowland rice, tobacco, coffee, citrus
Sta. Rita	Alcala	lowland rice	giant ipil-ipil, pasture, forestry, bamboo
Toran	Sta. Praxedes, Allacapan		lowland rice
Alaminos	Lallo		giant ipil-ipil, pasture, forestry, bamboo
Bantay	Rizal, Baggao	giant ipil-ipil, pasture, forestry, bamboo	
Carig	Gattaran		giant ipil-ipil, pasture, forestry, bamboo

Table 6. Recommended land use in the selected municipalities of Cagayan based on soil series.

Soil Series	Municipality	Existing Land Use	Recommended Land Use
Buguey	Buguey, Gonzaga, Sanchez Mira	coconut, vegetables, rootcrops	tobacco, peanut, pineapple, upland rice
Isabela	Amulung	lowland rice, vegetables	lowland rice
Quingua	Claveria, Sta. Teresita	lowland rice, corn, tobacco, sugarcane, peanut, mungbean	lowland rice, corn, upland rice, banana, sugarcane, coconut, tobacco, cassava, pineapple, mango, sorghum, peanut, citrus, onion, watermelon
San Fernando	Solana	lowland rice	lowland rice
San Manuel	Enrile, Tuao	corn, tobacco, and legumes diversified crops	corn, upland rice, banana, sugarcane, coconut, cassva, pineapple, mango, sorghum, watermelon, peanut, onion, tobacco, coffee, citrus
Sta. Rita	Alcala	lowland rice, corn, peanut, mongo, tobacco	lowland rice
Toran	Sta. Praxedes, Allacapan	lowland rice	pineapple, coconut, upland rice, banana, tobacco, cassava, mango, sorghum
Alaminos	Lallo	rice, corn, coconut, coffee, cacao, grass, forest	giant ipil-ipil, pasture, forestry, bamboo
Bantay	Rizal, Baggao	bamboo, grass, secondary forest	giant ipil-ipil, pasture, forestry, bamboo
Carig	Gattaran	upland rice, fruit trees, grass, vegetables, secondary forest	giant ipil-ipil, pasture, forestry, bamboo

Soil constraints and management options

Lowland rice (rainfed and irrigated)

Isabela (Amulung), Quingua (Claveria & Sta. Teresita), San Fernando (Solana) and Sta Rita (Alcala) series were identified as highly suitable to irrigated rice and these areas also have high potential for rainfed rice. In terms of soil characteristics and other factors affecting crop growth such as climate (rainfall and temperature) and topography are not considered a problem.

However, San Manuel (Enrile and Tuao) and Toran (Sta. Praxedes and Allacapan) series, rainfed rice is moderately suitable with soil fertility limitations. Since soil fertility is the problem, this can be corrected by proper soil fertility analysis and fertilizer recommendations.

Buguey (Buguey, Sanchez Mira and Gonzaga) series is considered marginally suitable for rainfed rice with soil physical properties (texture, soil depth, coarse fragments) limitations. The limitations mentioned can be corrected with a high cost. These limitations also indicate low fertility levels of the soils thus recommended to be planted to other suited crops and/or thru crop diversification. Alaminos (Lallo), Bantay (Rizal and Baggao) and Carig (Gattaran) series are noted as permanently not suitable to rainfed rice. These soils with severe limitations have characteristics such as topography and soil depth that cannot be corrected. The identified areas with severe limitations are those upland soils located in rolling to hilly mountainous areas.

Upland rice

Only Quingua (Claveria and Sta. Teresita) series was identified to be highly suitable to upland rice. Buguey (Buguey, Sanchez Mira and Gonzaga), Isabela (Amulung), and Sta. Rita (Alacala) series were identified as marginally suitable with soil physical properties (texture, soil depth, coarse fragments) and wetness (flooding and drainage) problems/ limitations. For Buguey series, a comprehensive soil analysis is needed to identify the fertility level for fertilizer recommendations. For Isabela series, drainage facilities and timing of planting is recommended to maximize income. For Sta. Rita series, drainage facility is recommended. Toran, San Fernando, Alaminos, Bantay and Carig series were not recommended for upland rice.

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