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Suitability mapping to support development of resilient communities and livelihoods in selected vulnerable communities in Cagayan Province, Philippines

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Key words: Agricultural, Climate change, Crop suitability, Gis modeling, Gis mapping.

Abstract

The inevitable effects of climate change in the agriculture sector are easily underestimated by agencies and stakeholders, having no means of quantifying them. For these effects to be accurately estimated, a system or method for calculation of the effects is needed. This paper addresses the problem through suitability modeling using GIS to evaluate the suitability of four primary crops like banana, coffee, pineapple and peanut using the relevant variables of slope, elevation, soil, land cover, rainfall, and temperature under RCP 4.5 scenario in municipalities of Amulung, Camalaniugan and Gonzaga, Cagayan, Philippines. It further investigated the suitability of the areas when hazards like flooding and landslide were considered. Results of suitability modeling revealed that pineapple is the most suitable followed by peanut, coffee, then banana. The final suitability maps generated showed that the suitable areas for production of the four different commodities changed greatly when the hazard component is included. Mitigation activities can be applied to increase the suitable areas for crop production. Adaptation through growing crops more resilient to climate change effects can also be undertaken.

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Introduction

Over the years, governments and other stakeholders assumed that disasters and natural hazards have equal effects and occurring in a cyclic manner. From this perspective, disasters and hazards are treated efficiently and/or excellently by technological solutions, such as large dams, storm surges barriers, and other techniques. However, the erratic and unescapable bleak conditions brought about by climatic change events such as typhoons, flood, changing rainfall patterns, drastic temperature changes, drought, erosion and landslides, and storm surges, undoubtedly have increasing impacts on the socio-economic welfare of the populace.

With agriculture as the primary economic sector in the Cagayan Valley Region, the impacts of climate change are extremely affecting the majority of the population that depends much of their livelihoods in various agri-aqua production activities. Accordingly, the Office of Civil Defense (OCD) in Cagayan Valley Region (Region 2), reported that the total damages due to floods alone from 2004 to 2006 reached about PhP 4.57 billion. From this amount, approximately 90 percent is accounted for damages to agriculture.

Climate change studies in the Philippines are emerging fast, focusing on different fields of sciences. Several climate change and vulnerability assessment (VA) studies (Jose and Cruz, 1999; Badjeck *et al.*, 2010; Sajise *et al.*, 2012; Perez *et al.* 2013) have in fact been conducted in the Philippines. The current proposal will not in any way duplicate these earlier studies and would in fact use the results of recent studies including those cited above to validate the suitability of selected agricultural commodities as climate resilient livelihood options for selected communities in the province.

Climate Smart Agriculture (CSA) is not a single specific agricultural technology or practice that can be universally applied (FAO 2013). It is an approach that requires site-specific assessments to identify suitable agricultural production technologies and practices. Scherr *et al.*, (2012) suggested that agricultural systems can achieve climate-smart objectives, including improved rural livelihoods as well as climate change adaptation and mitigation, through adopting a landscape approach. To be sustainable and climate resilient the needs of different stakeholders in a given landscape, land use planning as well as management of natural resources need to be coordinated across sectors and through a participative and consensus-based decision-making process. Achieving socio-ecologically sound landscape approaches will require building national and local capacity to develop responsible and inclusive governance arrangements which include improvements in tenure security and the recognition of the rights of individual and groups (FAO 2012).

Concerns on the impact of climate change on ecosystems and communities that depend on them have taken center stage in many if not all development interventions in recent years. However, the ability to effectively conserve ecosystems and the goods and services these provide depend to a large extent on the ability of the stakeholders to predict the impact of climate change and the communities' adaptive capacities to changes that may occur. Thus conservation efforts and interventions to mitigate the effects of climate change should consider the bio-physical factors to dictate the range of conservation and adaptations measures that could be effectively introduced and sustained over time.

Land Suitability is the degree of appropriateness of land for a particular use. Its assessment can be done for present condition or after improvement. According to Ritung *et al.*, 2007, some Land Evaluation Systems use several approaches such as parameters multiplying system, parameters totaling system, and matching system between land quality and land characteristics with crop requirements. Important land characteristics in any land evaluation include topography, soil, and climate (Ritung *et al.*, 20017). Also, Lupia 2012 made use of the parameters soil, precipitation, temperature, slope and land cover as the criteria addressing the suitability of the land for the crop cultivation in a given area.

In this study, GIS was applied to evaluate the suitability of four primary crops of Cagayan province like banana, coffee, pineapple and peanut using the relevant variables of slope, elevation, soil, rainfall, temperature under RCP 4.5 scenario in selected three municipalities. It further investigated the suitability of the areas when hazards like flooding and landslide were considered.

Material and methods

Study Site Selection

There were three municipalities that were selected as study sites based on vulnerability to climate change, resiliency and potential for agriculture and fisheries development, namely; Amulung, Camalaniugan and Gonzaga all of Cagayan, Philippines. Focus Group Discussion (FGD) and Key Informant Interview (KII) were conducted in three separate sessions for the three study sites. The local government officials assisted in gathering the barangay captains and the barangay agriculture and fishery council officers who served as respondents. Questionnaires were then answered by them based on the hazard experienced by their respective barangay.

The Municipal Agricultural Officer and the Municipal Planning and Development Officer of the study sites helped in explaining the different terminologies found in the questionnaires and assisted in answering such to ensure that the quality of the data gathered are reliable.

Crop Growing Requirement

The criteria developed for suitability assessment was based on relevant commodity production requirement guides. Climate variables such as rainfall and temperature, slope, elevation, soil, land cover and administrative maps were gathered and processed using GIS modeling to generate suitability maps.

Two hazards such as floods and soil erosion were integrated to generate the final suitability map of the selected commodities. Among the commodities chosen were banana, coffee, pineapple and peanut that were based on Philippine Rural Development Plan (PRDP). The suitability maps were validated by the local officials and farmers in the communities. The crop growing requirements of these commodities were also taken into account in evaluating their suitability. Parameters such as slope, elevation, rainfall, soil type, land cover and temperature that are best to grow the selected crops in the area were considered. The data of temperature and rainfall were provided by PAG-ASA while data on the other parameters were looked up online and was shown to the staff of the Provincial Planning and Development Office (PPDO) to determine its validity. Fig. 1 shows the flowchart for crop suitability.

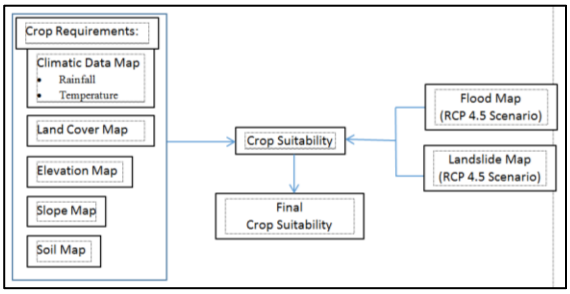
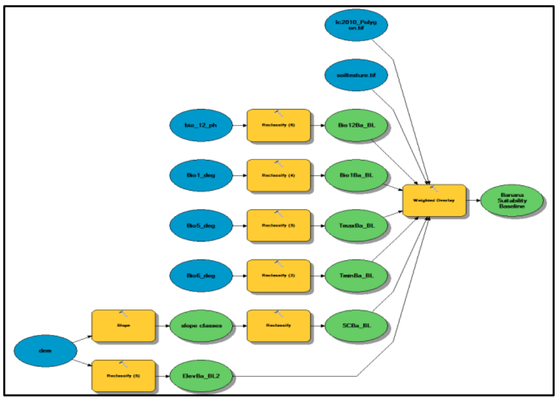


Fig. 1. Flowchart for Crop Suitability.

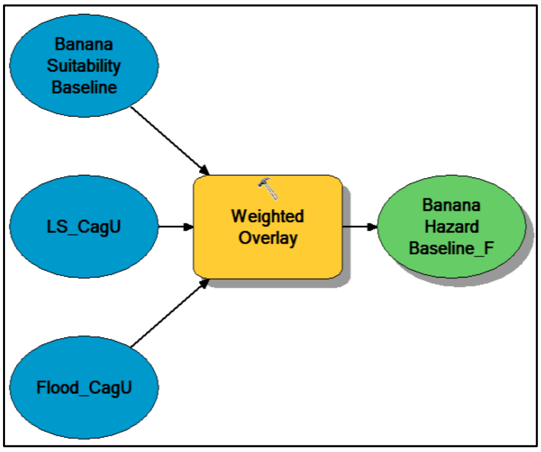
Crop Suitability Model

A GIS model integrating the parameters such as elevation, slope, rainfall, temperature, soils and land cover that is best to grow a specific crops with corresponding weights based on crop requirements was developed to generate the suitability map.

Another model was developed to generate the final crop suitability map integrating the effect of flood hazard and landslide hazard (Fig. 2).



(a)



(b)

Fig. 2. a). Crop suitability model b) Crop suitability model integrating the effect of Landslide and Flood hazards.

Suitability Mapping

After developing the suitability model, mapping was done using ArcGIS 10.3, first for the without hazards then landslide and flooding hazards were integrated all for the four commodities in the three municipalities. The data of temperature and rainfall were provided by PAG-ASA while data on the other parameters were looked up online and was shown to the staff of the Provincial Planning and Development Office (PPDO) to determine its validity.

Data Validation

After generating the suitability maps with and without hazards of each of the four commodities, these were shown to the municipal and barangay officials for validation. This process was done for all thee project sites. The previously generated maps were then revised taking into account the errors pointed out during the data validation activities. Field validation for focal survey and checking of the data gathered to ensure the quality, accuracy and validity of the data. This process took more than three days to finish.

Results and discussion

The Project Site

Cagayan is located at the northern part of the archipelago. It is bounded by two water bodies, the Pacific Ocean at the east and the Balintang Channel at the north. At its west, the provinces of Apayao and Ilocos are located and at its south, the provinces of Kalinga and Isabela. Traversing through the province is the longest river in the country, the Cagayan river (Fig. 3).

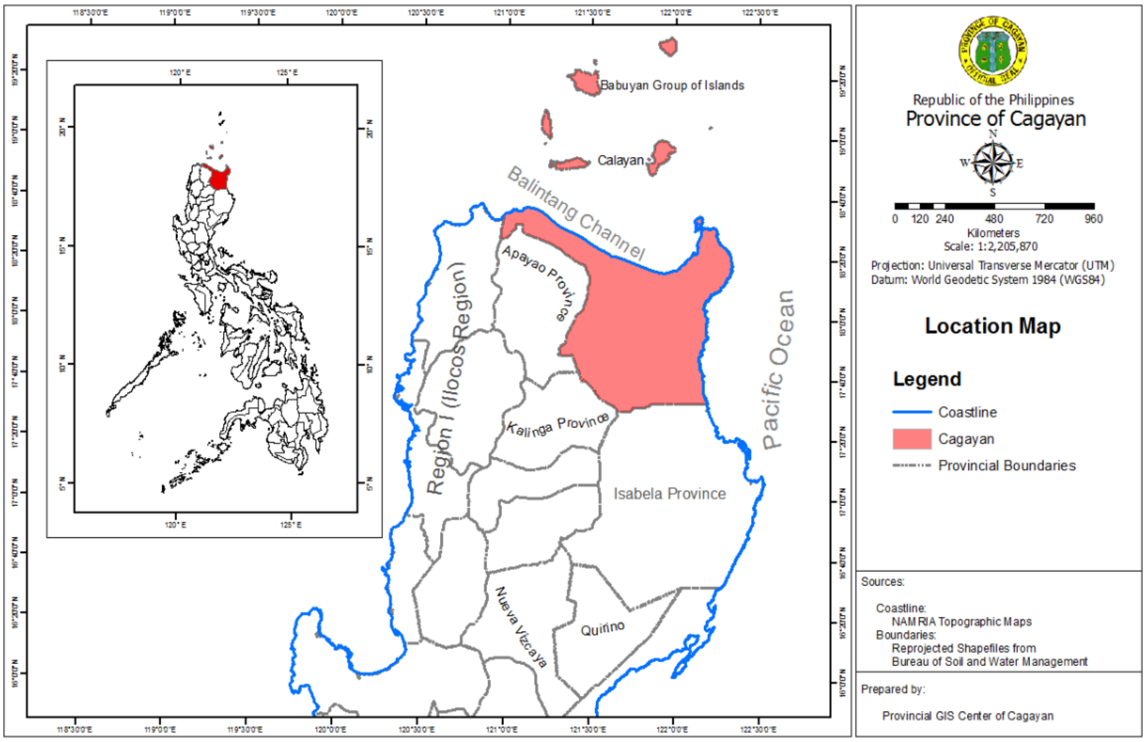


Fig. 3. Map of the project site showing its location. (Source: Cagayan PPDO).

Cagayan is vulnerable to different climate hazards. Its topography and location either helps the province against these hazards or these two are the sources of the hazards themselves. The Sierra Madre mountains which borders the province at the east lessens the effects of typhoons by serving as a barrier from strong winds. However, due to climate change, these mountain ranges were not able to protect the province from recent events like the first ever typhoon that was given an intensity level of signal No.5, typhoon Lawin in October 2016. Typhoon Lawin had a maximum wind speed of 225 kph. The topography of Cagayan makes it exposed to landslide. The Sierra Madre mountain ranges in the east, the Caraballo mountain ranges in the west and the Cagayan River which traverses in the area makes the province vulnerable to landslide.

Land Characteristics and Climatic Data

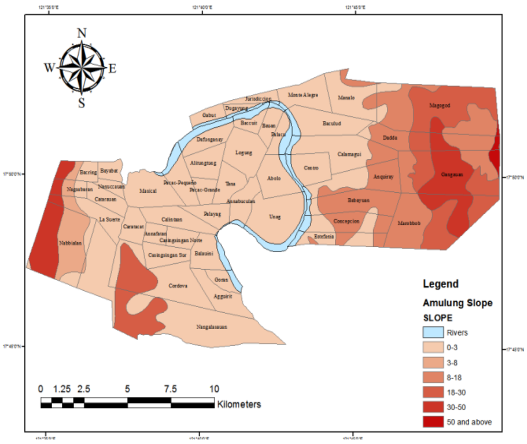
Slope

It can be observed that Amulung has moderately undulating to rolling lands at the eastern and western parts and level to gently sloping lands at its center. The very steeply sloping parts are where the mountains bordering the town from the east and the west can be located. This is one reason why it is sloping at those parts.

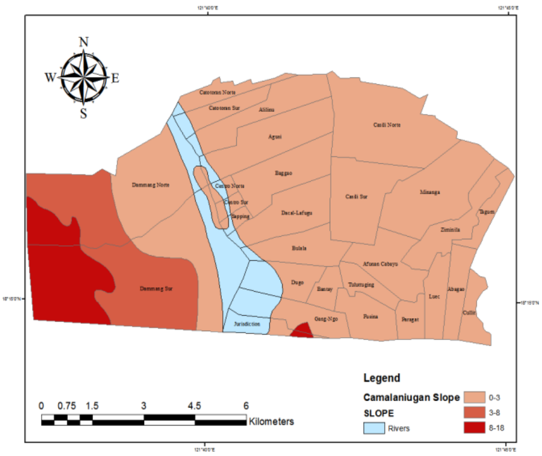
Camalaniugan terrain is classified into three categories represented by M, N, and O. Slope category M is described as level to very gently sloping lands with a slope range of 0-3 percent (7,251.04 hectares or 78.11%), N represents the gently sloping to undulating land, the slope range of 3 to 8 percent (1,532.13 hectares or 16.51%) and O that is best described as undulating to rolling lands with a slope range of 8-15 percent (499.3748 hectares or 5.38%). Gonzaga terrain is a mixture of various land terrain namely: the lowlands, the gently sloping to sloping lands, the sloping to hilly lands, and the hilly to mountainous lands. A rolling slope covers almost 49% of the total area of Gonzaga (Fig. 4).

Elevation

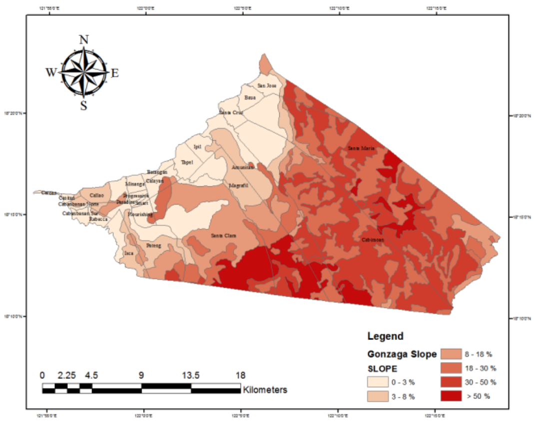
Majority of the municipal land area of Camalaniugan falls under; elevation <100 meters ASL (9,040.5448 hectares), characterized with the following topography such as very low relief, low relief, flat, and gently sloping relief; elevation of 100 meters to 300 meters ASL (242 hectares); elevation 300 to 500 meters ASL; and mountainous lands with elevation of 500 to 1,000 meters ASL.



Amulung



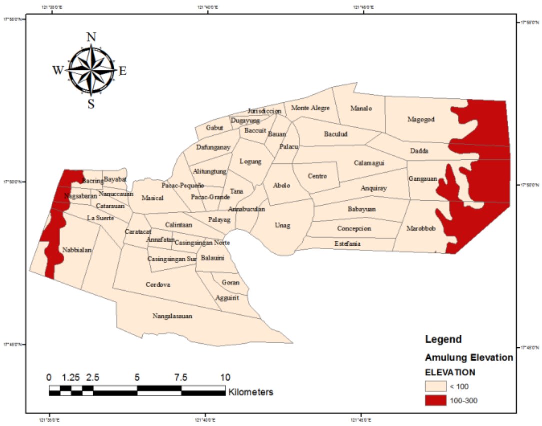
Camalaniugan



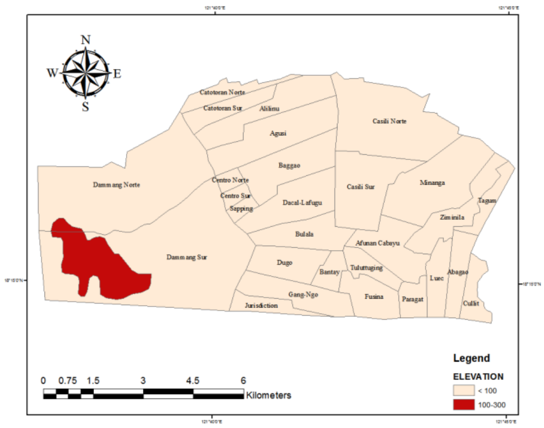
Gonzaga

Fig. 4. Slope Map of the municipalities of Amulung, Camalaniugan and Gonzaga.

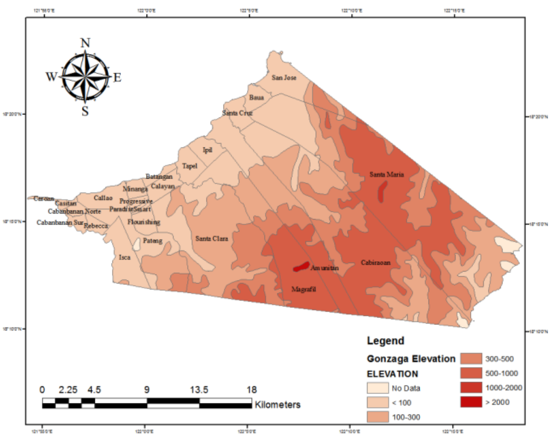
The municipal land area of Gonzaga is a mixture of various land terrain namely: the lowlands with elevation of less than 100 meters ASL; the gently sloping to sloping lands with elevation of 100 to 300 meters ASL; the sloping to hilly lands with elevation 300 to 500 meters ASL; the hilly to mountainous lands with elevation of 500 to 1,000 meters ASL (Fig. 5).



Amulung



Camalaniugan



Gonzaga

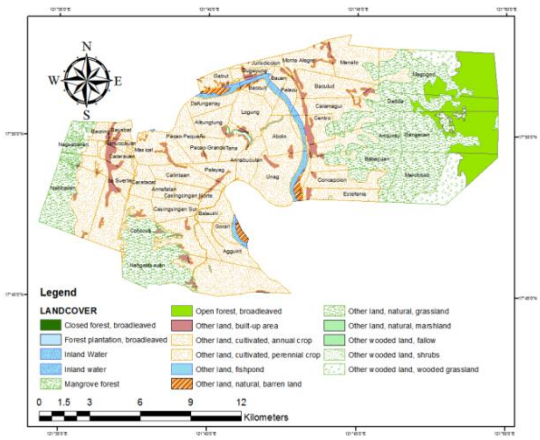
Fig. 5. Elevation Map of the municipalities of Amulung, Camalaniugan and Gonzaga

Land Cover

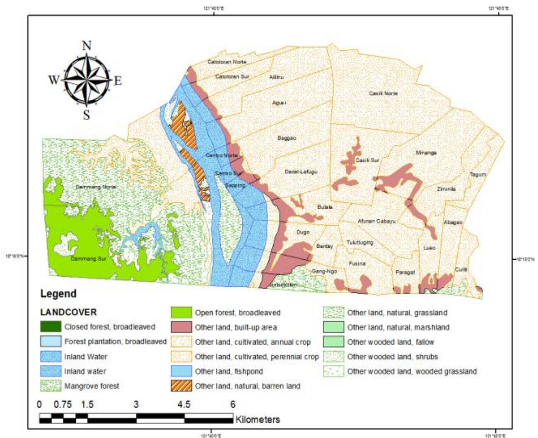
Some protected areas are present in the province. Protected landscape and seascapes are distributed throughout the province. In one of the selected project sites, there are two protected areas: the Baua River WFR and Wangag WFR in Gonzaga.

Gonzaga's vegetation covers more than three fourths of its municipal total land area. The forestlands are concentrated at the southeastern part of the municipality covering the headwaters of the various watersheds therein.

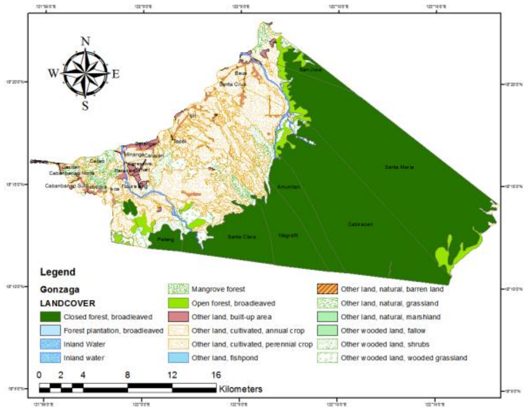
It has protection areas which include significant old growth forests, second growth forests, and at higher elevations, it has patches of mossy forests, areas with 1000 meters above sea level and with slopes greater than 50%, the Baua and Wangag Rivers Protected Watershed Reserves and 40 meters along both river banks (Fig. 6).



Amulung



Camalaniugan



Gonzaga

Fig. 6. Landcover Map of the Municipalities of Amulung, Camalaniugan and Gonzaga.

Soil

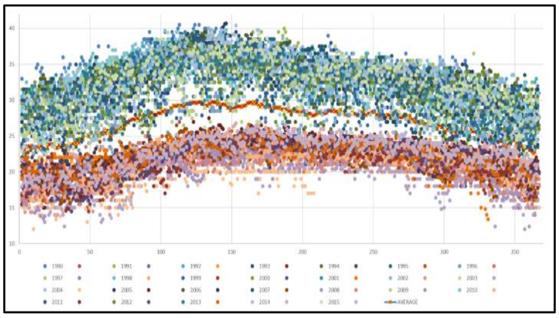
Amulung has 10 types of soil, namely: Quingua clay loam, Ilagan sandy loam-eroded phase, Bago sandy clay loam, San Manuel silt loam, San Manuel sandy loam, Sta. Rita clay loam, Isabela clay loam, Carig clay loam, Rock land, and Bantay clay loam. There are six soil series identified by the Bureau of Soils and Water Management in the municipality of Camalaniugan. They are Alaminos, Bantay, Bolinao, Buguey, San Miguel, and Toran. The record soil textures are clay, clay loam, loamy sand, silty clay loam, and silt clay. Toran silt clay manifest the widest area of coverage, about 4,106.0348 hectares or 44.23 percent. It is followed by Alaminos clay of 1,738.10 hectares, Bantay clay of 1,283 hectares, San Miguel silty clay loam with 603.12 hectares, Bolinao clay loam of 548.29 hectares and Buguey loamy sand of 439 hectares. An area of 565 hectares classified as water bodies.

Gonzaga has a conglomerate of various soil series and textures. These are the beach sand that covers an area of approximately 193.10 hectares along the coastal areas of the municipality; the Umingan sandy clay loam with an area of 158.43 hectares; the Toran Silty clay occupying an area of 180.53 hectares; the San Manuel silt loam which has an area of 1,846.06 hectares; the San Manuel sandy loam has an area of approximately 354.45 hectares, the Buguey sandy loam with an area of 1,123.72 hectares; the Quingua silt loam with an area of 812.10 hectares, the Alaminos Clay loam with an area of 6,547.01 hectares, Quinga clay loam covering an approximate area of 622.38 hectares ; the mountain soils undifferentiated encompasses areas in the forestlands and the areas remain unclassified is approximately 46,529.15 hectares.

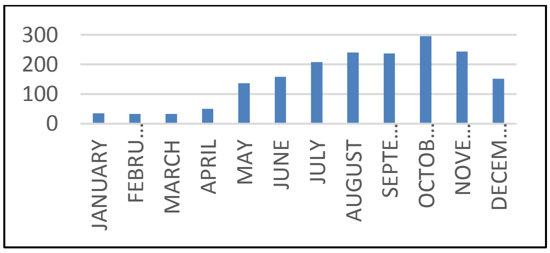
Rainfall and Temperature

There are only two weather stations in the province, one is located in Aparri and the other, in Tuguegarao. Twenty-five years of rainfall and temperature data of Tuguegarao and twenty years of the same set of data was obtained from PAG-ASA in the region. The weather data in Amulung are based from the Tuguegarao data and the weather data in Camalaniugan and Gonzaga are based from the Aparri weather due to the proximity of the project areas to the weather stations.

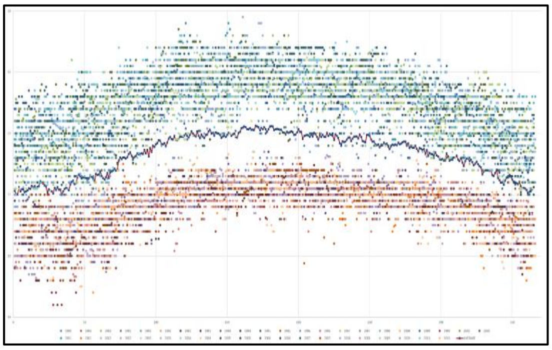
Tuguegarao has a daily temperature averaging from 22 to 29.8 degrees Celsius (25 year average) with highest temperature read of 40.7 degrees Celsius during the year 1995. Aparri experiences temperatures averaging from 24 to 29.6 degrees Celsius (20 year average) and peak of the wet season during November. Both Aparri and Tuguegarao experiences almost the same amount of rainfall during the peak of wet season, almost 300 mm (Fig. 7).



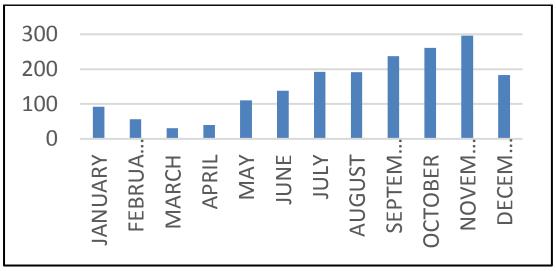
(a.1)



(a.2)



(b.1)



(b.2)

Fig. 7. (a.1) Tuguegarao Daily Temperature, (a.2) Tuguegarao Monthly Rainfall, (b.1) Aparri Daily Temperature and (b.2) Aparri Monthly Rainfall (Source: PAGASA).

Suitability Mapping of Key Commodities

The key commodities in the province were obtained from the available data in the Philippine Rural Development Plan (PRDP) online website. These are banana, coffee and pineapple. Peanut is added since it is widely grown in the area. These were mapped using suitability scales of 1-very low suitability, 2-low suitability, 3-moderate suitability, 4-high suitability and 5-very high suitability.

According to the commodity production requirement guide these commodities are best grown on the following: a) Banana (Saba) in loam soil with good drainage and aeration, uniform warm and humid conditions with a minimum rainfall of 60 inches annually, and a temperature between 27 and 30 °C; b) Coffee in temperature 21°C by night and 26°C by day, soil is medium texture with good drainage and erosion and well-distributed rainfall; and pineapple at 150-240 m ASL with a temperature of 24-30 °C, relatively uniform rainfall throughout the year and should be between 100-150 cm/yr, and sandy loam soil. Table 1 summarizes the weights of the criteria for the suitability mapping.

Table 1. Criteria and weight (%) for suitability mapping of the commodities.

Criteria	Banana	Pineapple	Coffee	Garlic	Peanut
Slope	15	10	15	20	15
Temperature	15	20	15	10	10
Elevation	10	10	10	10	15
Rainfall	20	20	20	20	20
Landcover	20	20	20	20	20
Soil	20	20	20	20	20

Banana

Generally, Amulung is moderately suitable for banana production. Areas located at Marobbob, Dadda, Magogod and Gangauan are restricted for banana production. In Camalaniugan, banana is highly suitable only at its western parts in Dammang Norte and Dammang Sur. Most of its land area is of low suitability. The mountainous part in Gonzaga is restricted in banana production. Other areas however, are moderately suitable.

In Amulung and Camalaniugan, suitability analysis with hazards revealed that there is a minimal change in the suitable areas for banana. In Gonzaga the highly suitable parts decreased by 1% and the moderately suitable parts increased by 1% (Fig. 8).

Coffee

The eastern part of Amulung which comprises of Marobbboob, Dadda, Gangauan and Magogod was considered to be restricted in growing coffee as they are located in high elevations. In Camalaniugan, coffee production is of low suitability, though areas in Dammang Norte are suitable. Generally, Gonzaga ranges from low to moderately suitable for coffee. Its mountainous part (Sierra Madre Mountain Ranges) were considered restricted.

Suitability map of Amulung showed that areas of high suitability were changed to moderately suitable. The highly suitable areas for coffee in Camalaniugan decreased by 1% while the low suitable areas increased by 1%. In Gonzaga, it showed the same situation: highly suitable areas decreased and either low or moderately suitable areas increased (Fig. 9).

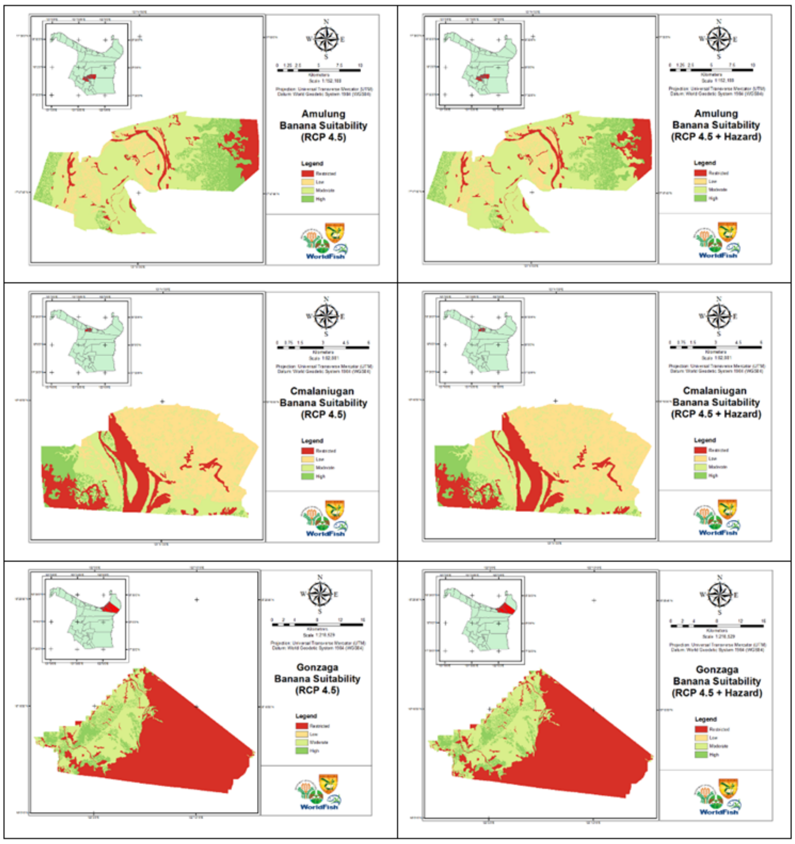


Fig. 8. Suitability Map of Banana under RCP 4.5.

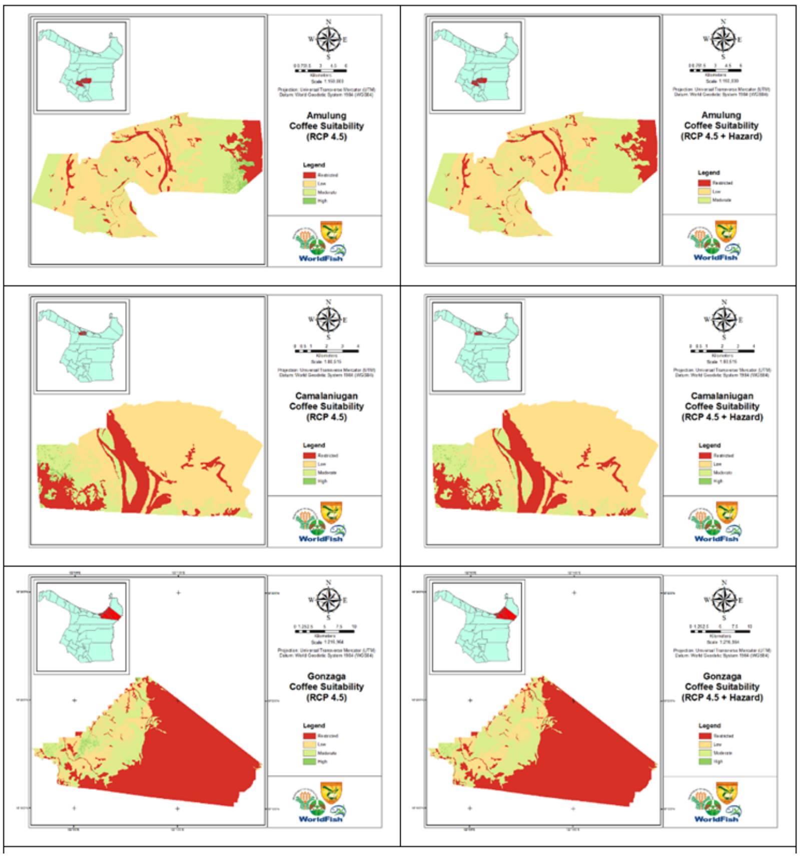


Fig. 9. Suitability Map of Coffee under RCP 4.5.

Pineapple

Amulung is highly suitable for pineapple production. Its eastern part has larger areas that are very highly suitable than the western parts. Generally, Camalaniugan is moderately suitable for pineapple production having its western parts that are highly suitable. Gonzaga is moderately suitable in pineapple production, with some distinctive parts for low suitability. Only small portions of the area are highly suitable for pineapple production. Further suitability analysis showed in Amulung that there is a decrease in highly suitable areas to moderately suitable by 15% . In Camalaniugan the change of highly suitable areas to moderately suitable areas is 4%. In Gonzaga the change of highly suitable areas to moderately suitable areas is only 1% (Fig. 10).

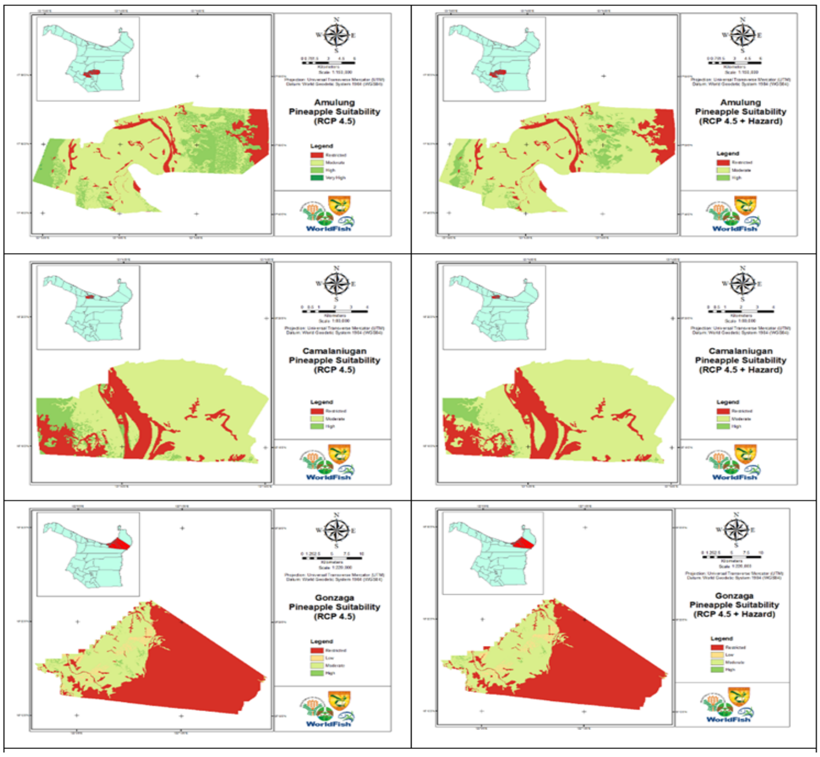


Fig. 10. Suitability Map of Pineapple under RCP 4.5.

Peanut

Amulung is moderately suitable for peanut production with some areas that are highly suitable. At its eastern portion, peanut production is restricted since these are areas with high elevations. Camalaniugan is moderately suitable for peanut of few at the western part that are highly suitable. Most of the land area of Gonzaga is restricted in peanut production because it is mountainous. There are portions that are moderately suitable with highly suitable at its northern part, specifically barangay Baua. There is a significant change of 11% of the highly sutiable areas to moderately suitable areas in Amulung. The shift in Camalaniugan and Gonzaga from high to moderate suitability is only 1% (Fig. 11).

Suitability Maps Validation

After the suitability maps were generated, they were validated by the Municipal Agriculture Officer (MAO), Municipal Environmental and Resources Officer (MENRO), Municipal Disaster Risk Reduction and Management Officer (MENRO), Municipal Planning and Development Officer (MPDO) together with their staff and field officers. This was reinforced by actual field observation. This is essential to evaluate the accuracy of the generated outputs. Inaccuracies were pointed out and necessary corrections were made. There were some insights left out during the FGD and KII on special cases within the barangays in the municipalities were also taken into consideration. The corrections pointed out by the municipal officials were considered in coming up with the final suitability maps.

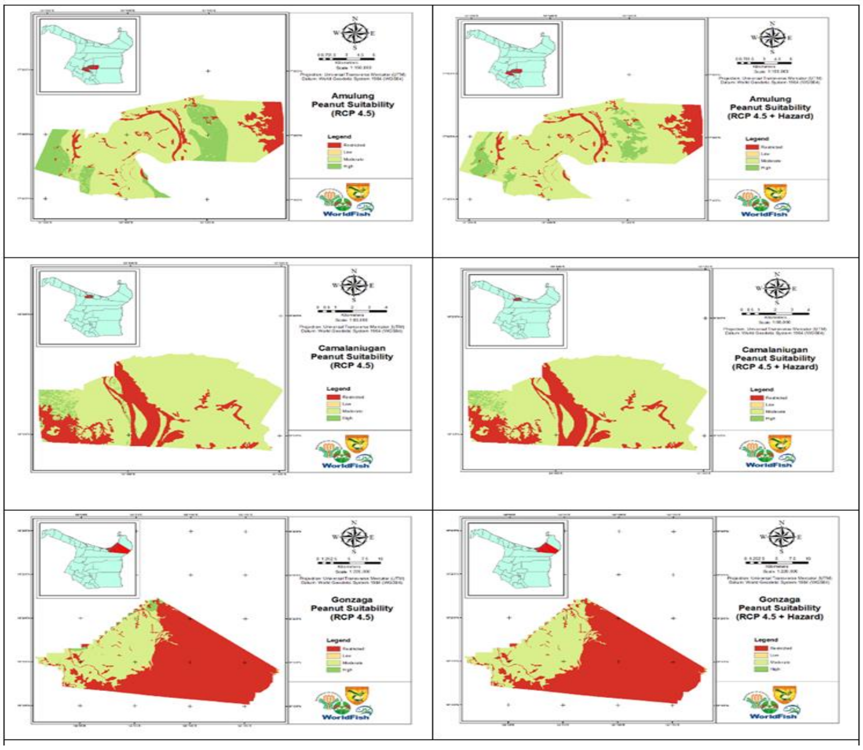


Fig. 11. Suitability Map of Peanut under RCP 4.5.

Conclusion

The suitability of banana, coffee, pineapple and peanut were studied under RCP 4.5 scenario without hazard and with hazard (flooding and soil erosion). Of the four crops, pineapple is the most suitable followed by peanut, coffee, then banana. The final suitability maps generated showed that the suitable areas for production of the four different commodities changed greatly when the hazard component is included.

Acknowledgement

The author wholeheartedly acknowledges DA-BAR and World Fish Philippines for the research grant in the conduct and completion of the research project. Gratitude is also extended to the Local Government Units of Amulung, Camalanuigan, and Gonzaga.

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