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Market Accessibility for Marginal Rice Grower in Papua New Guinea

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ABSTRACT: This paper examines statistical approaches for interpolating market related data over large regions, providing different interpolation techniques for market access variables used in agricultural research. Splines interpolation process was evaluated to distribute different variables related to market accessibility for total land area of Papua New Guinea. Different independent market access variables like village points, minor market, major market, capital market, telecommunication, airstrip and airports, major road network and major wharfs, were used for the interpolation process. Suitable market access zones were modeled using each independent market access variable. The accessible area was coded as 1 and rest area as 2 for each case. Overlay operation (intersection and union) was performed to find out the suitable market access zones using previously modeled seven types of market accessibility results. Then the final market accessibility layer was classified into 3 categories as Good, Medium and poor access. These market accessibility characteristics were applied to all the villages of Papua New Guinea to determine the market accessibility zone for each of them. Rice crop suitability analysis was carried out for entire Papua New Guinea base on multi-criteria decision-making approach using slope and altitude, soil texture, water holding capacity, soil depth, soil drainage, pH, exchange base saturation, nitrogen, potassium, phosphorus, temperature and rainfall data sets. Finally overlay analysis was carried out between market accessibility and suitable agriculture land zones for entire Papua New Guinea to show the prospects of rice cultivation for marginal farmer in term of market accessibility.

KEYWORDS: Geographic Information System, Spatial analysis, Agriculture, Market access, Mapping

1 INTRODUCTION

Papua New Guinea is located between the equator and 12°S latitude and consists of the eastern half of the large island of New Guinea and the Bismarck Archipelago and many other small islands. The majority of the Papua New Guinea peoples have subsisted on cultivation of non-cereal crops, such as tare, yam, banana, and sweet potato, and/or exploitation of sago palm. One of the most striking human ecological characteristics in this country is seen in different population densities in association with the environments where they have lived and the major foods which they have grown and eaten. Traditional food-production systems in Papua New Guinea can be broadly classified into four categories: two in the high-altitude zone and two in the low-altitude zone. In the high-altitude zone, sweet potato-dependent agriculture has been dominant in the central Highlands and taro-dependent agriculture in the Highlands fringe. In the low-altitude zone, cultivation of various crops, such as taro, yam, and banana, has been common in the eastern part of the main island and the islands region, whereas exploitation of sago has been prevailing in the western part of the main island. Interventions that improve transport and logistics infrastructure and services, including rural roads, motorized and non-motorized transport, storage facilities, markets, marketing and farm-to-market logistics, can have a substantial impact on reducing poverty and increasing food security. While initiatives are being implemented in countries of the region, physical access, especially in rural areas, remains a general problem. In some countries, 30 to 40 per cent of villages are without all-weather road access and minorities have no road access at all. In other countries, many road connections between the capital city and provincial capitals are unpaved and large percentages of provincial roads remain unpaved and may be impassable during the rainy season. This study mainly

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focused on the market access facility in the Papua New Guinea depending of some factors as-minor, major and capital market, telecommunication, airstrip transportation, major road transport and major wharfs.

2 STUDY AREA AND ITS PHYSICAL CONDITIONS

Papua New Guinea occupies the eastern half of the rugged tropical island of New Guinea (which it shares with the Indonesian territory of Irian Jaya) as well as numerous smaller islands and atolls in the Pacific. The Geographical Extension of Papua New Guinea is-0 degree to 12 degree south and 141 degree east to 160 degree east. The smaller island groups of Papua New Guinea include the Bismarck Archipelago, New Britain, New Ireland and the North Solomons. Some of these islands are volcanic, with dramatic mountain ranges, and all are relatively undeveloped. Nearly 85 percent of the main island is carpeted with tropical rain forest, containing vegetation that is a combination of Asian and Australian species. Papua New Guinea's climate is tropical, as one would expect in a country located just south of the Equator. December to March is the wet season, although occasional rain falls year-round. While Port Moresby, the capital, and other towns on the coast are quite hot in the summer months, temperatures are considerable cooler in the highlands.

3 DATA USED FOR THE STUDY

Different types of data are used for preparation of market accessibility map of different market access variables of Papua New Guinea, like village points, minor market, major market, capital market, telecommunication, airstrips and airports, major road network and major wharfs.

Table 1. Different data used for market access analysis

Market access variables	Year & Source
Village point, minor, major, capital & central markets	Geobook 2009
Mobile phone/telecommunication	Digicel Network coverage map, 2000 census
Airstrip transportation	PNG Airlines & Air Niugini, CAA, Geobook 2009 [1]
Major road/transport	PNGRIS 2009 [2] and Geobook 2009 [1]
Major wharf	PNG Ports, 2009 [1]

4 STUDY METHODOLOGY

4.1 SPATIAL INTERPOLATION

Interpolation predicts unknown values for cells in a raster from a limited number of sample data points. Unknown values are predicted with a mathematical formula that uses the values of nearby known points. The assumption that makes interpolation a viable option, this is spatially distributed objects as well as spatially correlated; in other words, things that are close together tend to have similar characteristics. Global interpolation techniques (e.g. IDWA) fit a model through the prediction variable over all points in the study area. Typically, global techniques do not accommodate local features well and are most often used for modeling long-range variations. Local interpolation techniques, such as splining, estimate values for an un-sampled point from a specific number of neighboring points. Consequently, local anomalies can be accommodated without affecting the value of interpolation at other points on the surface [3]. Splining, for example, can be described as deterministic with a local stochastic component [4]. Spline is an interpolation method that estimates values using a mathematical function that minimizes overall surface curvature, resulting in a smooth surface that passes exactly through the input points. Conceptually, the sample points are extruded to the height of their magnitude; Spline bends a sheet of rubber that passes through the input points while minimizing the total curvature of the surface. It fits a mathematical function to a specified number of nearest input points while passing through the sample points. This is a deterministic, locally stochastic interpolation technique that represents two dimensional curves on three dimensional surfaces [5], [6].

4.2 SPATIAL MODELING AND ANALYSIS

The easiest way to understand cell-based modeling is from the perspective of an individual cell as opposed to the entire raster. To calculate an output value for specified location (cell) using any spatial analyst operation or function, there are three things need to know- (i) the value of your specified location (cell), (ii) The manipulation of the operator or function and (iii) Which other cell locations and their values to include in calculations. This three-step process occurs for each location

(cell) in the raster dataset within any spatial analyst function. All operators and functions work on a cell-by-cell basis, and each calculation for each cell requires the value of the cell, the manipulation that is being applied, and other cell locations to include in the calculations. The spatial analyst operators and functions are grouped into categories based on how they manipulate values.

4.2.1 OVERLAY ANALYSIS

The overlay toolset contains tools to overlay multiple coverage to combine, erase, modify or update spatial feature into a new coverage. New information is created when one set of features is overlaid with another. There are five types of overlay operations; all involve joining two existing sets of features into a single set of features to identify spatial relationships between the input features. In all cases, the action coverage (for example, erase coverage) must be polygon coverage. The output coverage will contain the same feature class as the input coverage, and topology will be built.

4.2.2 PROXIMITY ANALYSIS

Using these operations, the characteristics of an area surrounding in a specified location are evaluated. This kind of analysis is called proximity analysis and is used whenever analysis is required to identify surrounding geographic features. The buffer operation will generate polygon feature types irrespective of geographic features and delineates spatial proximity.

4.2.3 MARKET ACCESS MODEL DESCRIPTION

Two types of accesses to market were marked for Papua New Guinea; they are (i) direct access to market and (ii) indirect access to market. Minor market, major market, capital and central market were considered as direct access to market and in the other hand telecommunication, airstrips and airports, major road network and major wharfs as indirect access to market. All the market access variables are used to build the market access layer for PNG. All the description for the market access variables are tabulated in the Table 2 & 3.

Table 2. Different market access variables and their description

Access	Mode of Access	Description
Direct access to market	Minor market	Village/roadside markets with settlement size of > 400 person
	Major market	Urban areas or townships e.g. Kainantu, Daru, Bukaua, Kwikila, Wabag. Market infrastructure available and depots for local trade settlement size of more than 1000 people excluding the capital and central market
	Capital and central market	Port Moresby, Lae, Kokopo, Goroka, Mt Hagen. Supermarkets
Indirect access to market	Mobile/telecommunication	Only Digicel network map was considered as a major telecommunication media
	Airstrips and airports	PNG Airlines (Airport) and Air Niugini map as point coverage
	Major road network	Foot track, minor road, major road, highway and boat way
	Major wharf	Major ports along the sea coast of PNG

4.2.4 MARKET ACCESSIBILITY FUNCTION

i. Travel by foot: The average time taken for farmer to travel by foot is approx 15 minutes per km. Therefore it would take = < than an hour to travel < 4 km.
ii. Travel by vehicle: The average speed to travel by vehicle under typical rural roads (unsealed) in PNG is 40 km/hr. A farmer will travel approx < 40 km in less than an hour.
iii. Travel by boat: It takes 2 hrs by dinghy using a 75 horse power motor engine from Lae to Bukawa which covers a distance of about 45 km. It would take about < less than an hour to travel 22 km. This does not consider the distance to travel by paddling in a canoe.

Table 3. Travel time and distance from village to access market

Direct access to market	Mode of access	Travel time from village	Distance from village (Km)		
			By walk	By motor car	By boat
	Minor market	<1hour	<4	<40	<22
	Major market	< 2 hours	<8	<80	<44
	Capital and central market	<3 hours	<12	<120	<66
Indirect access to market	Mobile/telecommunication	<1hour	<4	<40	<22
	Airstrips and airports	< 2 hours	<8	<80	<44
	Major road network	< 2 hours	<8	<80	<44

4.2.5 ARCGIS METHODOLOGY

The spatial analysis and modeling tool of ArcGIS was used to perform different overlay analysis, proximity analysis, interpolation and mapping (Chart 1). ERDAS IMAGINE was used to mosaic, geo-reference and re-project of all the individual province level data sets. Geobook [1] data sets were used for this purpose. For similar reference system re-project and transformation were performed to all the layers for individual provinces. All the data sets (all province level data set) were mosaicked to prepare the country level data sets, like village, informal market, formal market, capital market, telecommunication, airstrips and airports, major road network and major wharfs layers. Proximity analysis was performed using village points to generate market access zone using seven market access parameters. Overlay analysis was performed between each market access zone and village point layer, to determine the market accessibility zone for each of them. The accessible villages were coded as 1 and rest of the villages as 2 for each case. Statistical analysis (SUM) was performed of all coded village according to different mode of market access. Final village point layer was generated with total market access code and was classified into three market accessible ranks, like 7 to 9 as good (1), 10 to 11 as moderate (2) and 12 to 14 as poor market access (3) (Figure 1). Spatial interpolation was performed to distribute of the village points rank depending on market access facility for whole country with 500m spatial resolution. Final market access layer used to generate the final map of market accessibility for Papua New Guinea in the national level scale 1:5,000,000 (Figure 2). Reference market accessibility map for Morobe Province was produced (50 m spatial resolution) in the scale of 1:500,000.

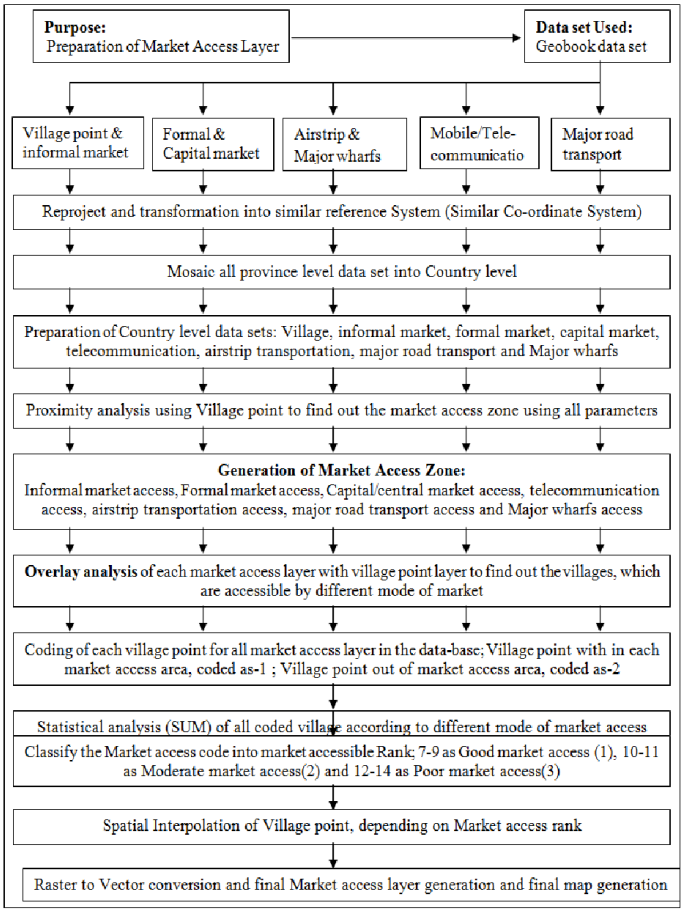

Chart 1. Methodological flow chart for market access analysis

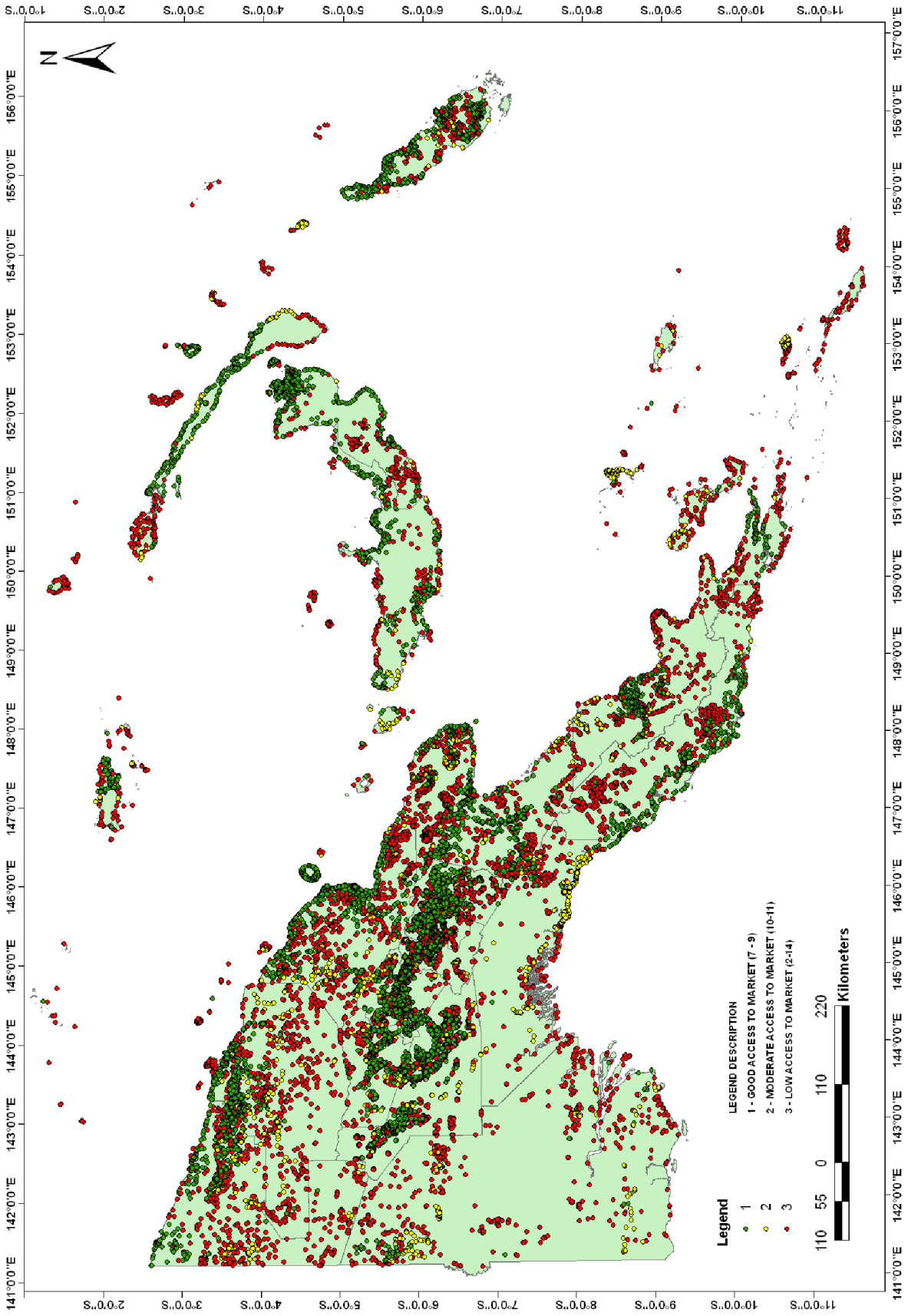

Fig. 1. Village points according to the rank of market accessibility of Papua New Guinea

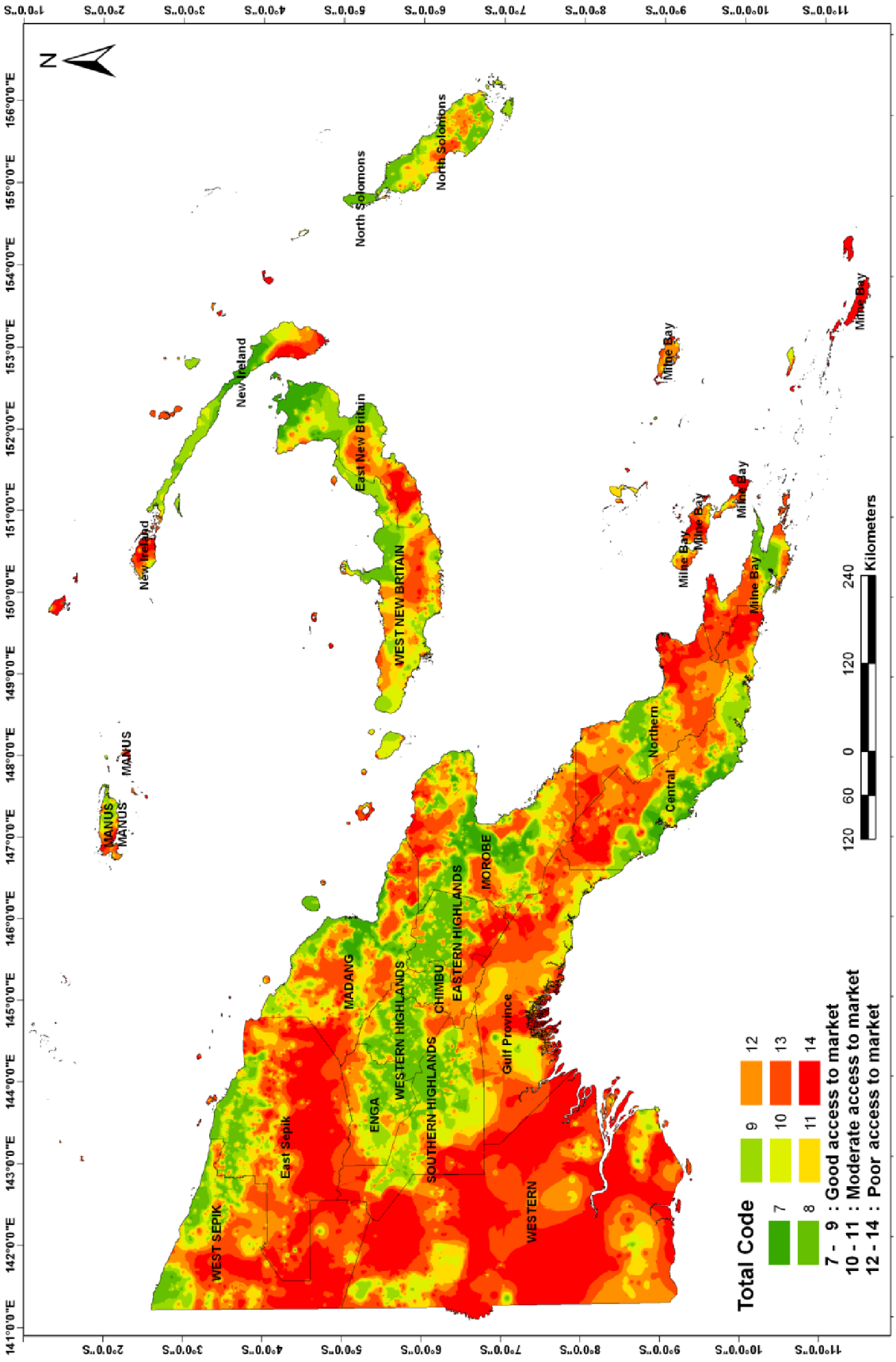

Fig. 2. Market accessibility zones in after calculating total code for each point of PNG

5 RESULTS AND DISCUSSION

Market accessibility analyses were evaluated at national level, province and district level. About 21850 numbers of villages were classified into three groups as good market accessibility (rank-1), moderate market accessibility (rank-2) and poor market accessibility (rank-3), displayed in Figure 1. Total 11637 numbers of villages (53.26 %) of Papua New Guinea were fall in good market accessibility group. 20.78% of land area of PNG fall in the rank one, 31.09 % in rank two and 48.12 % in rank 3. Province level market accessibility analyses were done for all 19 provinces of Papua New Guinea. The statistical analysis was done to find out the status of different market accessible zone under each province, shown in Table 4. 3.5 % land area (Papua New Guinea total land area as 100%) of Madang province came under good market accessibility (Rank 1). According to calculation of percentages of good market accessibility area in Papua New Guinea, Madang Province came in first followed by Morobe (2.65%), East Sepik (1.80%), North Solomon (1.70%), West New Britain (1.39%) etc. Western Highlands province having only 0.16% of goog suitability land area and ranked 19th in Papua New Guinea.

Table 4. Province level market accessibility analysis of Papua New Guinea

Province Name	Percentages of total area			Rank of Province
	Rank 1 (Good Accessibility)	Rank 2 (Moderate Accessibility)	Rank 3 (Poor Accessibility)	
Central	1.10	1.50	2.64	9
Chimbu	0.16	1.32	1.17	8
East New Britain	1.05	0.80	1.43	10
East Sepik	1.80	2.37	3.36	3
Eastern Highlands	0.42	2.42	1.86	15
Enga	0.41	1.53	1.71	16
Gulf Province	0.81	0.65	1.46	14
Madang	3.50	1.28	3.62	1
Manus	0.17	0.70	1.51	18
Milne Bay	0.90	2.12	4.06	12
Morobe	2.65	2.71	4.81	2
New Ireland	0.29	1.31	1.59	17
North Solomons	1.70	1.84	3.22	4
Northern	0.86	1.43	1.67	13
Southern Highlands	0.98	2.49	2.99	11
West New Britain	1.39	1.11	3.32	5
West Sepik	1.23	1.56	2.44	6
Western	1.21	1.61	3.72	7
Western Highlands	0.16	2.34	1.54	19
Total	20.78	31.09	48.12	

Rice crop suitability analysis was carried out for entire Papua New Guinea *(e.g. [7])*. Spatial multi-criteria decision-making approach is used with twelve geographical data sets, as input in the model, namely slope and altitude, soil texture, water holding capacity, soil depth, soil drainage, pH, exchange base saturation, nitrogen, potassium, phosphorus, temperature and rainfall. Erdas Imagine v-11 model builder/maker is used to build the key model for rice land suitability mapping. All selected provinces have been classified into five qualitative categories of rice land suitability. The final suitability output raster is classified into five categories of rice suitability. The result indicates that only fourteen percent (14%) land can be demarcated as 'high' and thirteen percent (13%) as 'moderate to high' suitability categories in the study area and the spatial expanse of all the five categories within the province are mapped and displayed (Figure 3). Zonal statistics algorithm is used to generate statistics for each suitability category that fall under each province based on final model output raster and province boundary feature (shown in Figure 4).

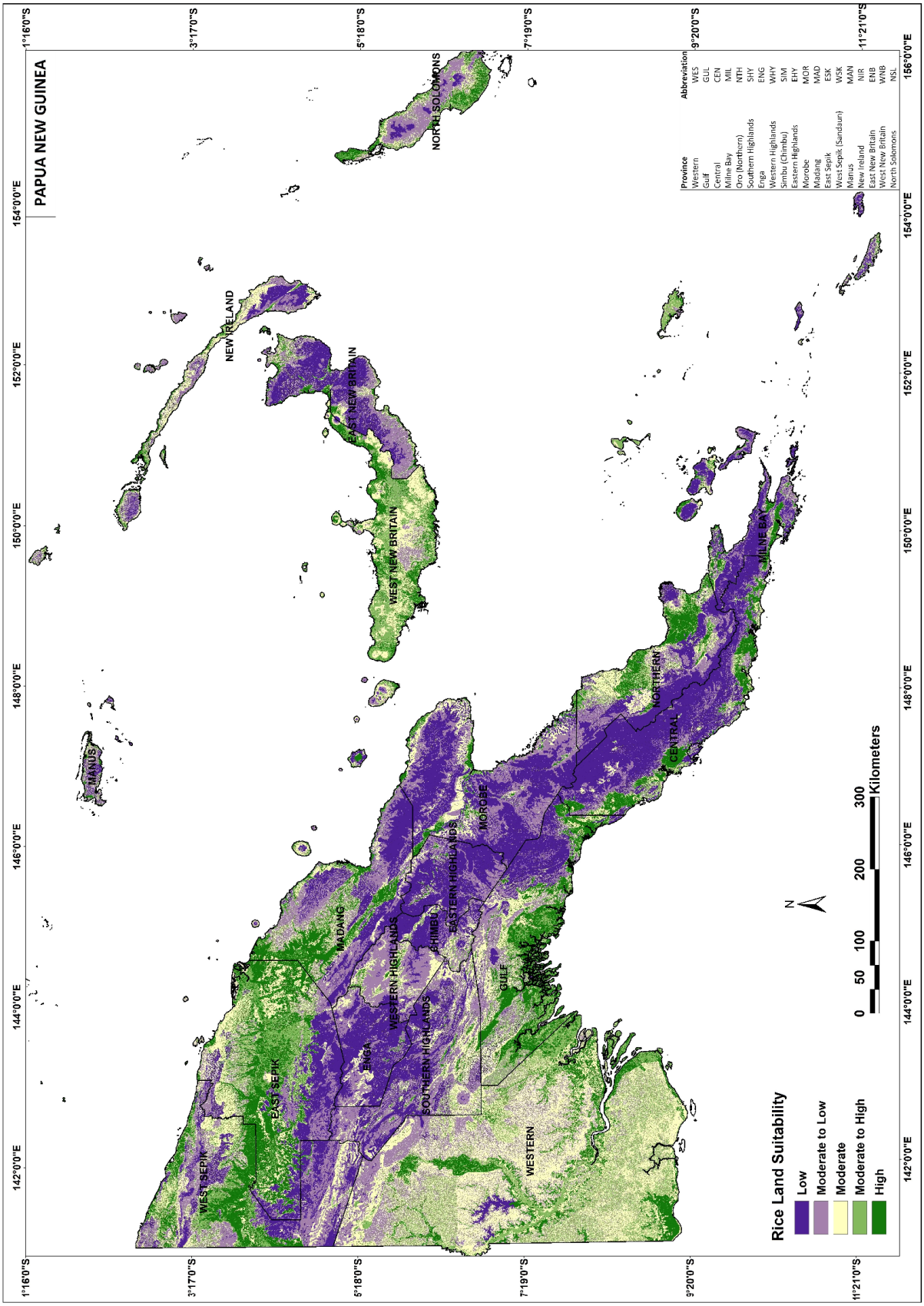

Fig. 4. Available suitable land for rice cultivation in Papua New Guinea

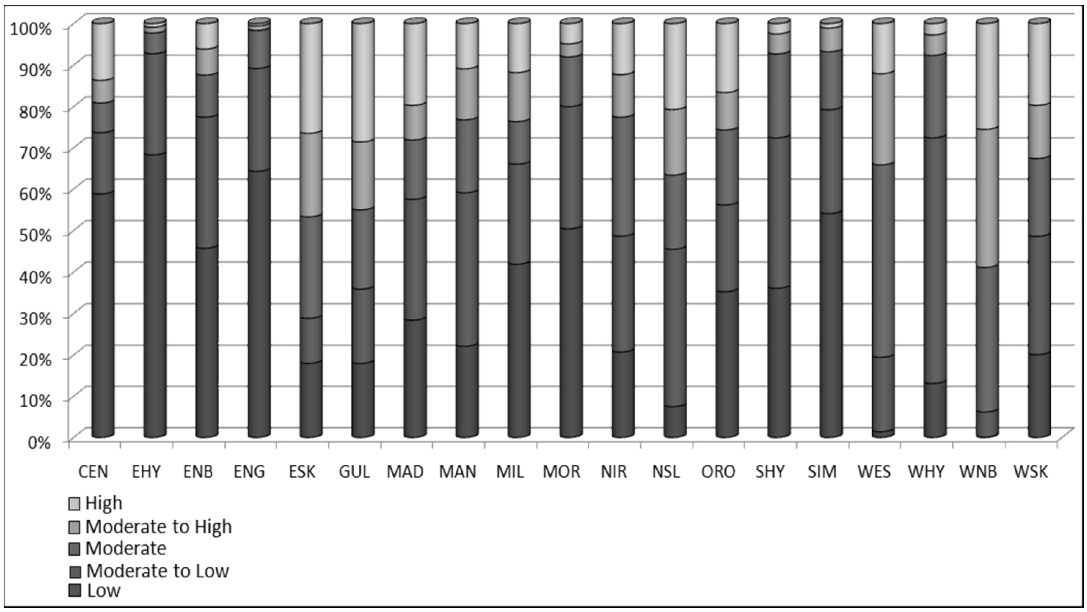

Fig. 3. Province wise availability of suitable land for rice in Papua New Guinea

6 CONCLUSION

The total study had been carried out for entire Papua New Guinea. Spatial interpolation (spline) was carried out to find out the accessibility zone of the country using the village points. In this case 500m spatial cell size (scale of 1:5000000) was chosen for interpolation process. In the province and district level 50m spatial cell size (scale of 1:500000) was considered to perform the spline interpolation. So the model in the ArcGIS can generate any scale of data set after supervising by the user. Village, informal market, formal market, capital market, telecommunication, airstrips and airports, major road network and major wharfs were choose as independent parameters to establish the market accessibility for each village of PNG and we got better result after cross checking in different places of the different provinces of the country.

Overlay analysis of good market accessibility zones and suitable agriculture land zones was performed for entire Papua New Guinea to show all the suitable places are suitable for rice cultivation, may or may not come under good market accessibility. The result shows (Table 6) around 2.8% of "high" (out of 14%), 2.06% of "Moderate to high" (out of 13%) and 3.38% of "moderate" (out of 24%) suitable rice land area fall under good market accessibility zone.

Table 6. Market accessibility vs Rice land suitability zone in Papua New Guinea

Rice Land Suitability		Market accessibility (% area)		
Suitability class	Suitable area (%)	Good	Moderate	Poor
Low	26	5.20	6.01	14.56
Moderate to Low	23	3.91	5.19	13.70
Moderate	24	3.38	5.57	14.15
Moderate to High	13	2.06	3.50	7.70
High	14	2.82	3.97	8.29

PNG's unique geography and infrastructure deficiencies, however, present a major challenge. Until as recently as the 1930s, parts of the New Guinea Highlands, which have supported thriving agricultural communities for thousands of years, remained almost completely isolated from the outside world. The foremost symbol of PNG's infrastructure ailment is its 700km Highlands Highway. Countless other problems exist in PNG at the micro level, such as simple access to vehicles to bring vegetables to market. The nation's large supermarkets literally run out of food during holiday periods. Better roads, bridges, and ports could solve many problems in PNG, but these require large investment, as well as a level of technical and managerial expertise the nation simply does not possess

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