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Title

MARKET ACCESS AND AGRICULTURE SUITABILITY ANALYSIS USING GIS TECHNIQUE

A CASE STUDY ON MOROBE PROVINCE, PAPUA NEW GUINEA

Author(s)

Sailesh Samanta
Department of Surveying and Land Studies,
PNG University of Technology,
Private Mail Bag, Lae-411, Morobe Province, Papua New Guinea

Babita Pal
Department of Surveying and Land Studies,
PNG University of Technology,
Private Mail Bag, Lae-411, Morobe Province, Papua New Guinea

Dilip Kumar Pal
Department of Surveying and Land Studies,
PNG University of Technology,
Private Mail Bag, Lae-411, Morobe Province, Papua New Guinea

Wycliffe Antonio
Department of Surveying and Land Studies,
PNG University of Technology,
Private Mail Bag, Lae-411, Morobe Province, Papua New Guinea

Abstract:

This study used an empirical methodology for analysis and mapping of the crop suitability and market accessibility using GIS techniques. 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. Tension method of Spline interpolation process was evaluated to distribute different variables related to market accessibility for total land area of Morobe province, 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. District level market accessibility analyses were done for nine districts of Morobe province to find out the status of each district in relation to the market accessibility. On the other hand climate, soil and slope of the area were used to find out suitable zone for agriculture process. Finally suitable agriculture zone map was overlaid on the market accessibility map for better understanding.

Keywords: GIS, spatial modeling, spatial analysis, agriculture suitability, market access

1. Introduction:

Three major climatic types are found in Papua New Guinea. First type of climate is called “A-type climate”. It covers most of PNG and is characteristics by high temperatures and high rainfall. Second type of climate is called “C-type climate”. This is the climate found in the highland valleys where there is rainfall all year but the average temperature is lower due to altitude. Third type of climate is recognized as “E-type climate”. This type of climate only found in the highest area of Papua New Guinea where temperature are much lower, usually average 10°C or Less and there is high rainfall all the year (Samanta et.al., 2011). The majority of the

Papua New Guinea's 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. This study mainly focused on the market access facility depending of some factors, as minor, major and capital market, telecommunication, airstrip transportation, major road transport and major wharfs and agriculture suitability based on climate, soil and slope.

2. Study area and data used:

The study area is Morobe province is bounded within 145° 30' E to 148° E longitude and 5° S to 8° S latitude. Different types of data were used for preparation of market accessibility and agriculture suitability map of Morobo province, like village points, minor market, major market, capital market, telecommunication, airstrip transportation, major road transport, major wharfs, climate, soil and slope. One of the most widely used digital elevation model (DEM) data sources is the elevation information provided by the shuttle radar topography mission (SRTM) (Coltelli et al. 1996), but as with most other DEM sources, the SRTM data requires significant levels of pre-processing to ensure that there are no spurious artifacts in the data that would cause problems in later analysis such as pits, spikes and patches of no data (Dowding et al. 2004). In the case of the SRTM data, these patches of no data are filled, preferably with auxiliary sources of DEM data, like topographical maps. Both data sets used for this study. Optical bands with standard false color combination (SFCC) of Landsat-7 ETM+ satellite images were used to find out the land use/land cover classes in the study area. All other details of the variables, data spans along with the sources were given in the table 1.

Table 1. Different data used for market access and agriculture suitability analysis

Sl. No.	Market access variables	Year & source of data
1	Village point, minor, major, capital & central markets	Geobook, 2009 census update
2	Mobile communication	Digicel Network coverage map, LLG, 2000 census
3	Airstrip transportation	PNG Airlines & Air Niugini, CAA, Geobook, 2009
4	Major road/transport	RAMS & NEFC, Geobook, 2009
5	Major wharf	PNG Ports, 2009
6	Soil maps	Geobook, 2009
7	Topographical maps	University of Texas Libraries, Austin
8	SRTM data	*ftp://e0srp01u.ecs.nasa.gov*
9	Landsat-7, ETM+	University of Maryland Institute for Advanced Computer Studies

3. Methodology:

3.1. Techniques used in the study

3.1.1 Spatial interpolation

Interpolation predicts values for cells in a raster from a limited number of sample data points. It can be used to predict unknown values for any geographic point data. 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. Interpolation methods can also be described as "global" or "local." Global 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 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. Splining, for example, can be described as deterministic with a local stochastic component (Burrough and McDonnell, 1998). 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. (Eckstein, 1989; Hutchinson, and Gessler, 1994). Splining may be thought of as the mathematical equivalent of fitting a long flexible ruler to a series of data points. There are two types of spline method, they are regularized method and tension method. The regularized method creates a smooth, gradually changing surface with values that can lie outside the sample data range and the tension method controls the stiffness of the surface according to the character of the modeled phenomenon. It creates a less smooth surface with values more closely constrained by the sample data range.

3.1.2. 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 in two categories based on how they manipulate values.

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 different 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.

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.

3.2. Market access model description

Two types of accesses to market were marked for Morobe, i.e. (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, airstrip transportation, major road transport and major wharfs as indirect access to market.

3.2.1. Variables for market access

All the market access variables, like village (points), minor market (points), major (points), capital market (points), telecommunication (area), airstrip transportation (points), major road transport (lines) and major wharfs (points) were used to build the market access layer for Morobe. All the description for the market access variables were tabulated in the table 2.

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, wholesale mkts and export points
Indirect access to market	Mobile phone/ telecommunication	Only Digicel network map was considered as a major telecommunication media
	Airstrip transport	PNG Airlines (Airport) and Air Niugini map
	Major road/transport	Foot track, minor road, major road, highway and boat way
	Major wharf	Major ports along the sea coast of PNG

3.2.2. Market accessibility

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.

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.

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. All the description for the market accessibility in order to travel distance and time were tabulated in the table 3.

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
	Airstrip transportation	< 2 hours	<8	<80	<44
	Major road/transport	< 2 hours	<8	<80	<44

The spatial analysis and modeling tool of ArcGIS was used to perform different overlay analysis, proximity analysis, interpolation and mapping purpose. ERDAS IMAGINE was used to mosaic, geo-reference and re-project of all the individual province level data sets. Geobook 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 make the country level data sets, like village, informal market, formal market, capital market, telecommunication, airstrip transportation, major road transport and major wharfs layers. Proximity analysis was performed using village points to generate market access zone using all market access parameters. Overlay analysis of each market access zone with village point layer to find out the villages are accessible by different mode of market or not. Coding of each village point for all market access layer in the data-base; village point with in each market access area, coded as-1 ; village point out of market access area, coded as-2. 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 (3) market accessible ranks, like- 7-9 as good market access (1), 10-11 as moderate market access (2) and 12-14 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 in 50m spatial resolution. Final market access layer used to generate the final map of market accessibility for Morobe province, Papua New Guinea (in 50 m spatial resolution) in the scale of 1:500,000 (Figure 2).

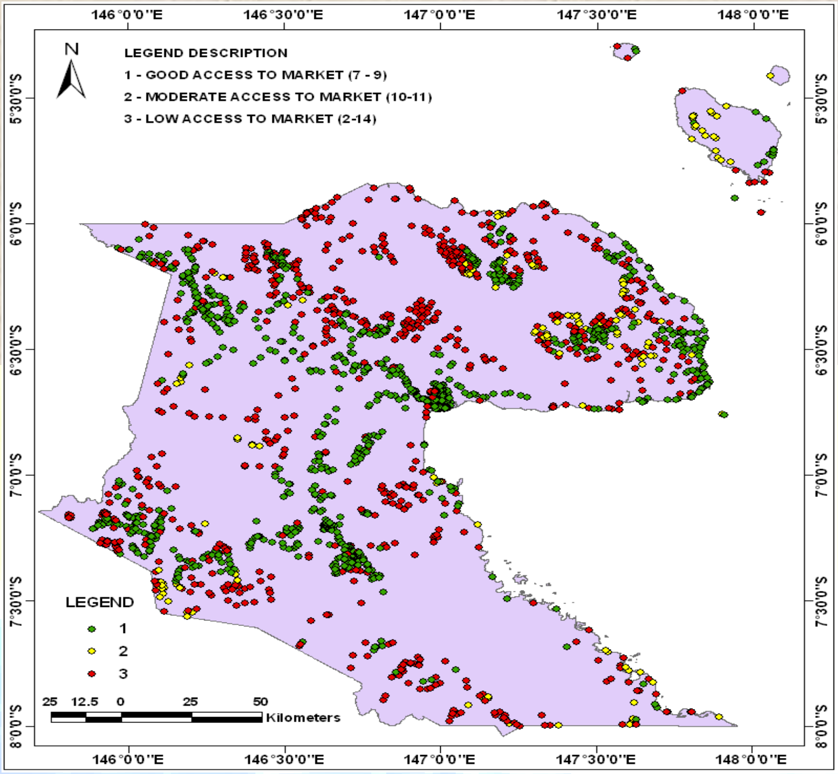

Figure 1. Village level market accessibility based on market access model of Morobe province

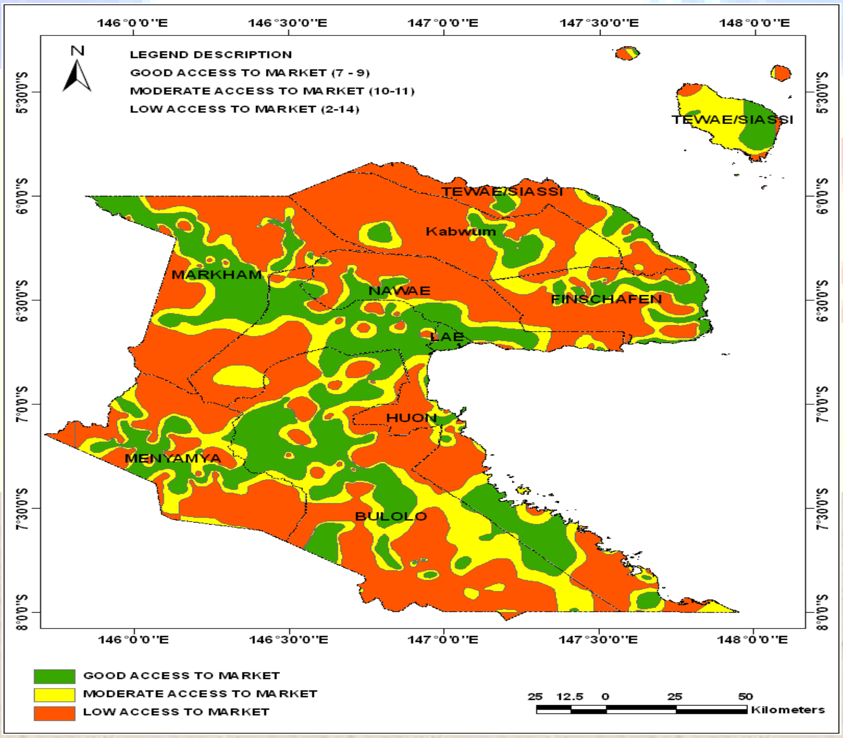

Figure 2. Details market accessibility zones of Morobe (District level)

3.3. Agriculture suitability model description

In the ArcGIS s/w environment climate, soil and slope layers were generated with the help of soil map, station rainfall and temperature data, digital elevation model, SRTM data and satellite data. Using Erdas imagine model maker we find out the suitable agriculture zone based on above said parameters. The model description was shown in the chart 1.

4. Results and discussion:

Market accessibility analyses were evaluated at province and district level. The model calculation was done for the nine districts of Morobe province to find out the status of each district in relation to the market accessibility, displayed in table 4. 91.77 % land area of Lae district came under good market accessibility, where as Kabwum district of Morobe showing 72.38% of land area under poor market accessibility. All the districts of Morobe were coded with a new rank according to the nature of market accessibility, displayed in last column in table 4. According to calculation of percentages of good market accessibility area, Lae district came in first followed by Huon, Markham, Bulolo, Nawae, Finschafen, Tewae, Menyamya and Kabwum. We established the relationship between the market accessibility and suitable agriculture zone by overlaying process (Figure 3). All suitable agriculture zones were not highly accessible by the market. Maximum portion of the Lae district come under both the suitable agriculture and good market access zone than other district of Morobe province.

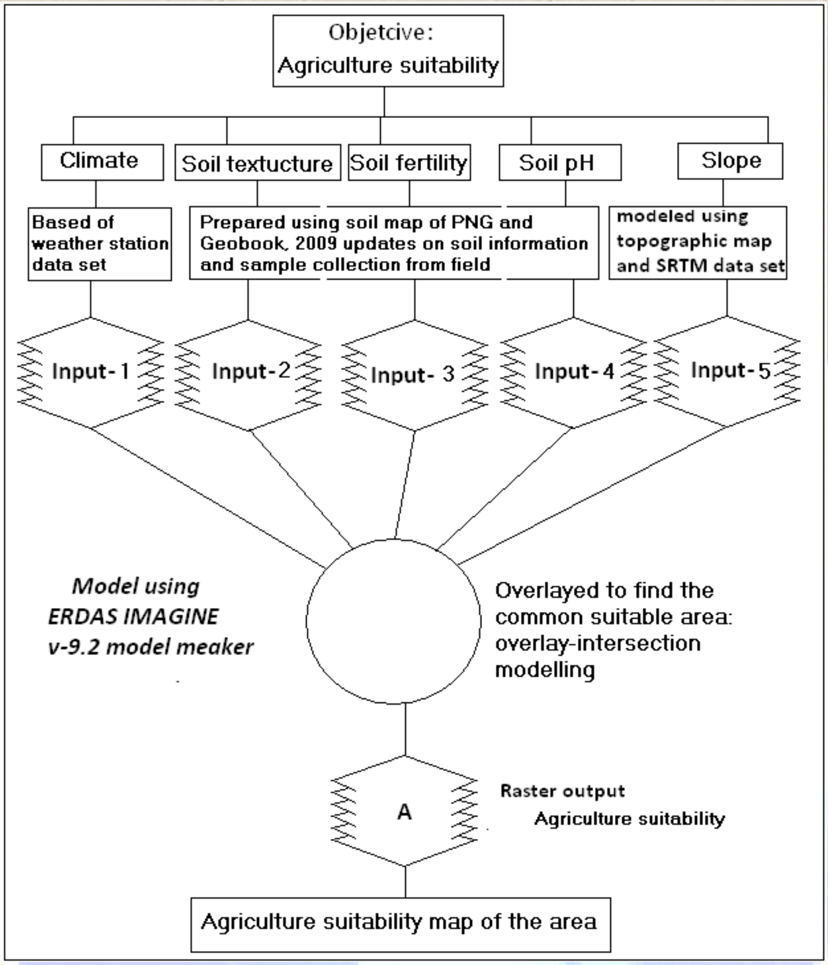

Chart 1. Methodological flow chart for the preparation of agriculture suitability map

Table 4. District level market accessibility analysis of Morobe province, Papua New Guinea

Sl. No.	District name	Percentages of total area under different market access				Rank of district according to accessibility
		Good access	Moderate access	Poor access	Total area	
1	Tewae/Siassi	19.48	31.86	48.66	100	7
2	Bulolo	28.17	28.47	43.36	100	4
3	Huon	30.94	23.15	45.91	100	2
4	Lae	91.77	4.32	3.91	100	1

5	Menyamya	18.81	24.14	57.05	100	8
6	Markham	29.79	16.14	54.07	100	3
7	Kabwum	10.21	17.41	72.38	100	9
8	Nawae	24.06	17.73	58.21	100	5
9	Finschafen	20.48	27.35	52.16	100	6
Morobe Province		24.67	23.62	51.71	100	

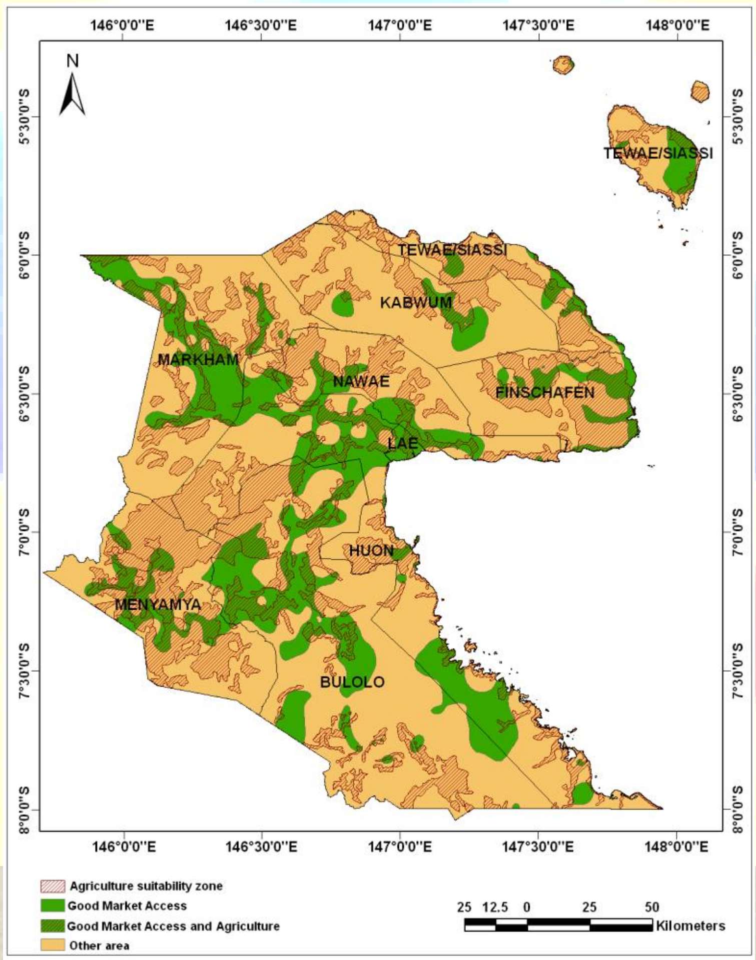

Figure 3. Overlay map of good market access zones & suitable agriculture zones

5. Conclusions:

The total study had been carried out for entire Morobe province, 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 50 m spatial cell size (scale of 1:500000) was chosen for interpolation process. The model in the ArcGIS can generate any scale of data set after supervising by the user. Overlay analysis of good market accessibility zones and suitable agriculture zones was carried (Figure 3) for of Morobe province only to prove that all the places where cultivation were performed, may not come under good market accessibility. Village, informal market, formal market, capital market, telecommunication, airstrip transportation, major road transport and Major wharfs were choose as independent parameters to establish the market accessibility for each village of Morobe and we got better result after cross checking in different places in the study area. In the future study we can go for micro level and national level mapping on the same after adding of updating the parameters used in the present study.

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