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# Systems Approach to Disaster Risk Reduction in Comprehensive Land Use Planning of San Jose City, Nueva Ecija, Philippines

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**Abstract**

In the Philippines, mainstreaming disaster risk reduction (DRR) in the development plans of local government units (LGUs) was emphasized in Republic Act 10121, in response to the Hyogo Framework of Action. In this study, the methodological framework of integrating DRR in the comprehensive land use plan (CLUP) using a systems approach was developed and operationalized using the case of San Jose City, Philippines. In the Geographic Information Systems (GIS)-assisted analysis, the city's land area was divided into 1-hectare (ha) by 17,203 grids. Five land use types, namely: tomato, bitter melon, rice, onion, and residential areas, were reviewed in terms of vulnerability using multiple goal linear programming (MGLP). The disaster risk of the city, as a function of hazard, exposure, and adaptive capacity, was assessed using climate scenarios for 2035 along with extreme events on flooding, drought, rain-induced landslides, and earthquake. The city registered mean scores of exposures (2.74), susceptibility (3.69), and lack of adaptive capacity (2.52), as well as a mean vulnerability index of 11.02, which is relatively low compared to the highest possible score of 25. The hazard susceptibility score is expected to increase from 1.18 under the current condition to 1.42 under the 2035 scenario. Consequently, the disaster risk is expected to increase from 12.98 to 15.6 within the same period. Areas along the river network scored higher in terms of hazard. Under the current and 2035 scenarios, target crop production for selected crops – rice, onion, tomato, and bitter melon – is predicted to be met with the potential to increase farmers' net income based on the proposed land use allocation. Moreover, the allocation can minimize the disaster risk of the city to 0.53 and 1.45, meeting the demand for safe residential areas of 567.87 ha in the current scenario, and 970.05 ha based on predicted population growth rates for the 2035 scenario. A systems approach is vital in optimizing land use allocation considering development goals and disaster risks of LGUs.

*Keywords: optimal land use allocation, disaster risk reduction, vulnerability, hazard*

## 1. Introduction

Disasters happen when communities find it difficult to cope, and their functioning is disrupted after a hazardous event. Disasters, due to the occurrence of extreme events associated with global warming and climate change, have increased by 50 percent from the 1950s to the 1990s (UN-Habitat, 2007).

UNISDR (2005) emphasized that the starting point for reducing disaster risk lies in the knowledge of the hazards and vulnerabilities and of how these are changing on a temporal scale. Thereafter, actions may be taken based on the assessment. Among the action plan under the Hyogo Framework for Action 2005-2015 is the reduction of underlying risk factors through land-use planning. This was cascaded to the Philippines through RA 10121 or the Philippine Disaster Risk Reduction and Management (PDRRM) Act of 2010, which ensures the integration of disaster risk reduction (DRR) into the local development plans, programs, and budgets as a strategy toward sustainable development and poverty reduction. Land use planning is the most fundamental tool for mainstreaming DRR and climate change adaptation into urban or town development processes (UN-Habitat, 2007), as it seeks to mitigate the risks and vulnerability from several geological and hydrologic hazards (Nojavan, Sadeghian, Mohajeran, & Sobani, 2012) by keeping people and property out of hazardous areas, providing more affordable housing and living conditions, protecting the environment, and reducing the costs of growth and development (Simonovic, 2011).

A systems approach can help decision-makers in selecting the best course of action in land use allocation by providing a better understanding of the interrelatedness of different components of the system, by broadening the scientific information base, and by facilitating the prediction of the consequences of the options (Simonovic, 2011).

The Land Use Planning and Analysis System (LUPAS,) framework was adopted and modified to integrate disaster risk reduction in the comprehensive land use plan of a local government unit (LGU). Different development and climate scenarios were constructed, and land use options were presented to provide the LGU with a basis for decision-making.

## 2. Methods of Research

### 2.1 Study Area

San Jose City, Nueva Ecija, Philippines is a third-class city located 160 km north of Manila. It has a total land area of approximately 18,725 ha (CPDO, 2011). San Jose City was chosen as the study site because it is prone to four natural hazards namely, flood, agricultural drought, landslide, and earthquake. Its CLUP is on pending status for approval of Provincial Land Use Committee (PLUC) and Housing and Land Use Regulatory Board (HLURB) and has not integrated DRR yet.

### 2.2 Procedure

Adopted from the LUPAS framework developed by Roetter, et al. (1998) and Coladilla (2006), the following are the components of the operational methodology of the study: Component 1 – Goals and objectives identification; Component 2 – Resource balance and land evaluation; Component 3 – Yield estimation; Component 4 – Input/output estimation; and Component 5 – Multiple Goal Linear Programming. The databases needed are: Database 1 – Biophysical Resources; Database 2 – Socio-Economic Resources; Database 3 – Hazard and Vulnerability; and Database 4 – Policy Views and Development Plans. The third database was added to consider disaster risk reduction and climate change adaptation.

The susceptibility of an area to four natural hazards, namely flood, drought, landslide, and earthquake was determined by generating maps. Flood and drought hazard susceptibility maps were generated using ArcGIS 10.2 out of the formulas:

$$\text{Flood} = \Sigma\ 0.5Rf + 0.2Sg + 0.14St + 0.11LU + 0.05Dr$$

$$\text{Drought} = \Sigma\ 0.42Rf + 0.18Tm + 0.16Gwp + 0.07Lc + 0.05Lu + 0.12St$$

where,

**Rf:** rainfall
**Sg:** slope gradient
**St:** soil texture

The weights of the factors were derived using Analytical Hierarchy Process (AHP), developed by Saaty (1977), through the Delphi Technique. A total of six (6) experts in the field of geology (2), agricultural engineering (2), agricultural science (1), and hydrology and water resource (1) were asked for their responses. Landslide hazard susceptibility map was generated using Stability Index MAPping (SINMAP) software of Project NOAH. The earthquake hazard susceptibility map was produced from Rapid Earthquake Damage Assessment System (REDAS) software devised by the Philippine Institute of Volcanology and Seismology (PHIVOLCS).

**Lu:** land use
**Dr:** distance from the river
**Tm:** mean temperature
**Gwp:** groundwater potential
**Lc:** land cover

The four hazard susceptibility maps were overlaid through GIS using the weights evaluated by the disaster management experts of the city.

$$H_i = 0.40\sum_{i=1}^{ni} Fl_i + 0.20\sum_{i=1}^{ni} Dr_i + 0.20\sum_{i=1}^{ni} Ls_i + 0.20\sum_{i=1}^{ni} Eq_i$$

where,
**Fli:** flood susceptibility index score in grid i
**Dri:** drought susceptibility index score in grid i
**Lsi:** landslide susceptibility index score in grid i
**Eqi:** earthquake susceptibility index score in grid i

Vulnerability is a function of exposure, susceptibility, and lack of adaptive capacity. An index score of each factor of every component was computed by subjecting values to log normalization and standardize the values and units. Exposure of the elements at risk was computed considering the index scores of population density, household assets, and agricultural area of each barangay translated into grid data.

$$E_i = \sum_{i=1}^{ni} PI_i + \sum_{i=1}^{ni} HA_i + \sum_{i=1}^{ni} AA_i$$

where,
**PIi:** population density index score in grid i
**HAi:** household assets index score in grid i
**AAi:** agricultural area index score in grid i

The susceptibility of the barangays to natural hazards was determined using the formula below. The weights of the factors were based on the 2011 World Risk Report.

$$S_i = \sum_{i=1}^{ni} 0.2857PI_i(0.5W_i + 0.5HC_i) + 0.1429N_i + 0.2857P_i(0.5D_i + 0.5PL_i) + 0.2857G_i$$

where,
**PIi:** public infrastructure index score in grid i
**Wi:** percent of households without access to water index score in grid i
**HCi:** housing condition (percent of households living in makeshift housing in each barangay) index score in grid i
**Ni:** nutrition (population who are undernourished in each barangay) index score in grid i
**Pi:** poverty and dependencies in grid i
**Di:** dependency ratio index score in grid i
**PLi:** poverty level (percent of households below extreme poverty in each barangay) index score in grid i
**Gi:** Gini index score in grid i

Lack of adaptive capacity (AC) is a function of gross enrollment ratio, gender parity, adaptive strategies, and public health expenditure, i.e.

$$AC_i = \sum_{i=1}^{ni} 0.25GER_i + 0.25GP_i + 0.25AS_i + 0.25PH_i$$

where,
**GERi:** gross enrollment rate index score in grid i
**GPi:** gender parity index score in grid i
**ASi:** adaptive strategies index score in grid i (level of knowledge; the level of awareness on projects; the level of preparedness)
**Phi:** public health expenditure index score in grid i

The level of adaptive strategies of the people was sought through household surveys. This was measured by giving scores to the level of knowledge on hazards, level of awareness on government projects regarding DRR, and level of preparedness of people on hazards. The respondents were selected using stratified random sampling.

The study employed ArcGIS 10.2 (license end-user number 235027) for GIS processing, Microsoft Excel for data storage, and Gurobi *(free academic license grbgetkey 2daed634-9d54-a14e-049c-58eb04eca57e)* for linear programming and optimization.

## 3. Results

The framework is a science-based methodology for mainstreaming disaster risk reduction into the comprehensive land use plan of a local government unit. A systems approach to land use optimization was introduced to the conventional CLUP 12-step process prescribed by the HLURB in 2013 (Fig. 4). The methodological framework constructed was based on LUPAS developed by Roetter, et al. in 1998. The 12- step process in formulating CLUP prescribed by the HLURB will not be changed but rather, the systems approach to optimal land use allocation integrating DRR was the modification introduced in the framework. Legal bases of mainstreaming DRR in CLUP were the Hyogo Framework for Action 2005-2015 cascaded in Republic Act 10121 or the Philippine Disaster Risk Reduction Management Act of 2010.

Six objective functions emerged from the alignment of development goals from national to household level, namely: (1) Maximize rice production; (2) Maximize onion production; (3) Maximize tomato production; (4) Maximize bitter melon production; (5) Maximize residential suitability, and (6) Minimize disaster risk in the city.

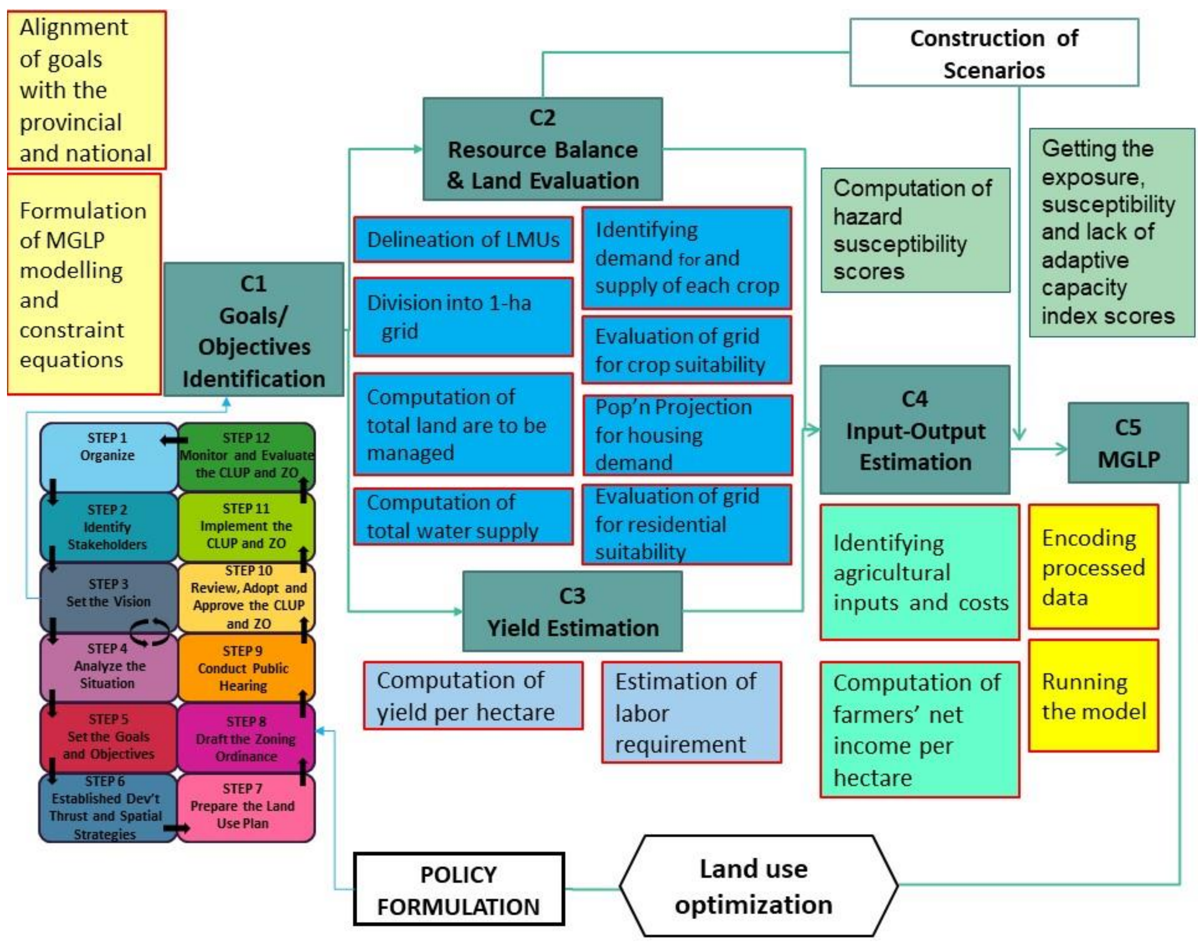


Figure 1. Detailed methodological framework

Agricultural production systems of four crops were analyzed (Table 1). San Jose City produced 88,279 MT of rice planted in 9,102 ha. Tomato and bitter melon had low yields and small areas of production; however, demands for these products were high.

Table 1. Area planted, total yield and demand for crops in San Jose City, 2015

| Crop | Area Planted* (ha) | Yield* (mt) | Demand (mt) |
|---|---|---|---|
| Rice | 9,102.19 | 88,279.10 | 16,653.04 |
| Onion | 979.25 | 10,021.00 | 528.95 |
| Tomato | 15.09 | 180.00 | 1,095.13 |
| Bitter melon | 8.25 | 28.00 | 329.88 |

Source: City Agriculture Office (CAO)

Future scenarios up to the year 2035 were constructed in terms of extreme events and demographic changes. For extreme weather events, 95 mm of rainfall was added to the average total monthly rainfall of baseline using the raster calculator of GIS to simulate the worst flood scenario or the highest rainfall in 50 years centered in 2035 under Representative Concentration Pathway 4.5 (RCP4.5) scenario. For the drought scenario, 70 mm was subtracted from the baseline data such that heterogeneous rainfall all over the area was demonstrated. To complete the drought scenario, 2ºC was added to the average monthly mean temperature of the baseline.

Landslide hazard is based on an extreme climate scenario of having a rainfall intensity of 100 mm/hr generated by the SINMAP software of Project NOAH. The same map was used for both current and 2035 scenarios. For the current condition, an 8-year return period earthquake hazard susceptibility map was produced from REDAS software devised by PHIVOLCS using magnitude 6.9, with epicenter originating from 121.17 longitude and 15.68 latitude. 23.3-year return period earthquake was simulated having a magnitude of 7.2 and keeping other attributes constant. New levels of hazard susceptibility scores were generated.

From 2008 to 2015, the average population growth rate of San Jose City is computed at 1.47 percent. It is envisioned that the population will increase from 143,596 in 2015 to 154,321 in 2020 which might require the conversion of 78.53 ha of agricultural land to support residential needs. The 2015 population is projected to increase 191,640 in 2035.

The grids were rated as moderately susceptible under the current condition and highly susceptible under extreme event scenarios to flooding. A total of 421.64 ha of the existing residential area under normal condition was classified as moderately susceptible and 455.72 ha under extreme event scenario was scored as highly susceptible to flooding.

The areas on both sides of the Talavera River were rated with high susceptibility to agricultural drought under normal conditions. The rest of the city was moderately susceptible to agricultural drought. During extreme events, 57 percent or 10,764.76 ha of the total land area of the city would be highly susceptible to drought.

The rainfall-induced shallow landslide susceptible areas under the worst-case scenario reveal that low, moderate, and high susceptible areas were concentrated in the forest areas of the city which were sparsely inhabited by people.

In a 6.9 magnitude earthquake scenario with an 8-year return period, low-lying areas are predicted to be moderately impacted. On the other hand, the mountainous part is generally predicted to receive low earthquake impact. A 6.9 magnitude earthquake scenario with a 23-year return period will likely impact a total area of 2,642.34 ha concentrated in some portions of barangays Porais, Tulat, Palestina, Culaylay, Palestina, San Agustin, and Kaliwanagan.

In overlaying flood, drought, landslide, and earthquake maps, the flood map was given the highest weight of 0.4, while the rest of the hazards have been given a weight of 0.2. This yielded the mean hazard index score of 1.18 for San Jose City with low lying areas receiving an index score of below 1, indicating almost no susceptibility to any hazard. The areas along with the river network of the city, however, received a hazard index score between 1.01 to 2.0. Meanwhile, the overall moderate susceptibility of the mountainous parts of the city is largely due to the moderate to high susceptibility to landslides (Fig. 2).

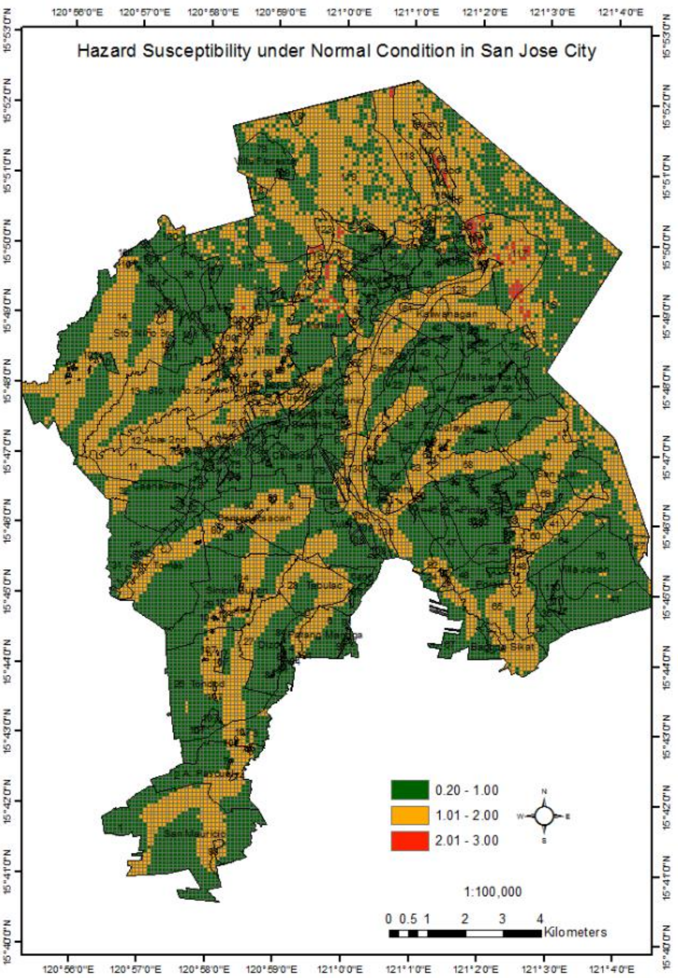


Figure 2. Hazard susceptibility under normal condition in San Jose City, Nueva Ecija, Philippines

Under the extreme event scenarios, the average hazard susceptibility score of the city is 1.42. The land area of the city covered by hazard susceptibility score ranging from 2.01 to 3.0 is calculated at 2,958.49 ha, mostly found along the river. Areas along the river and on the mountainous part of the city obtained a score ranging from 1.01 to 2.0 (Fig. 3).

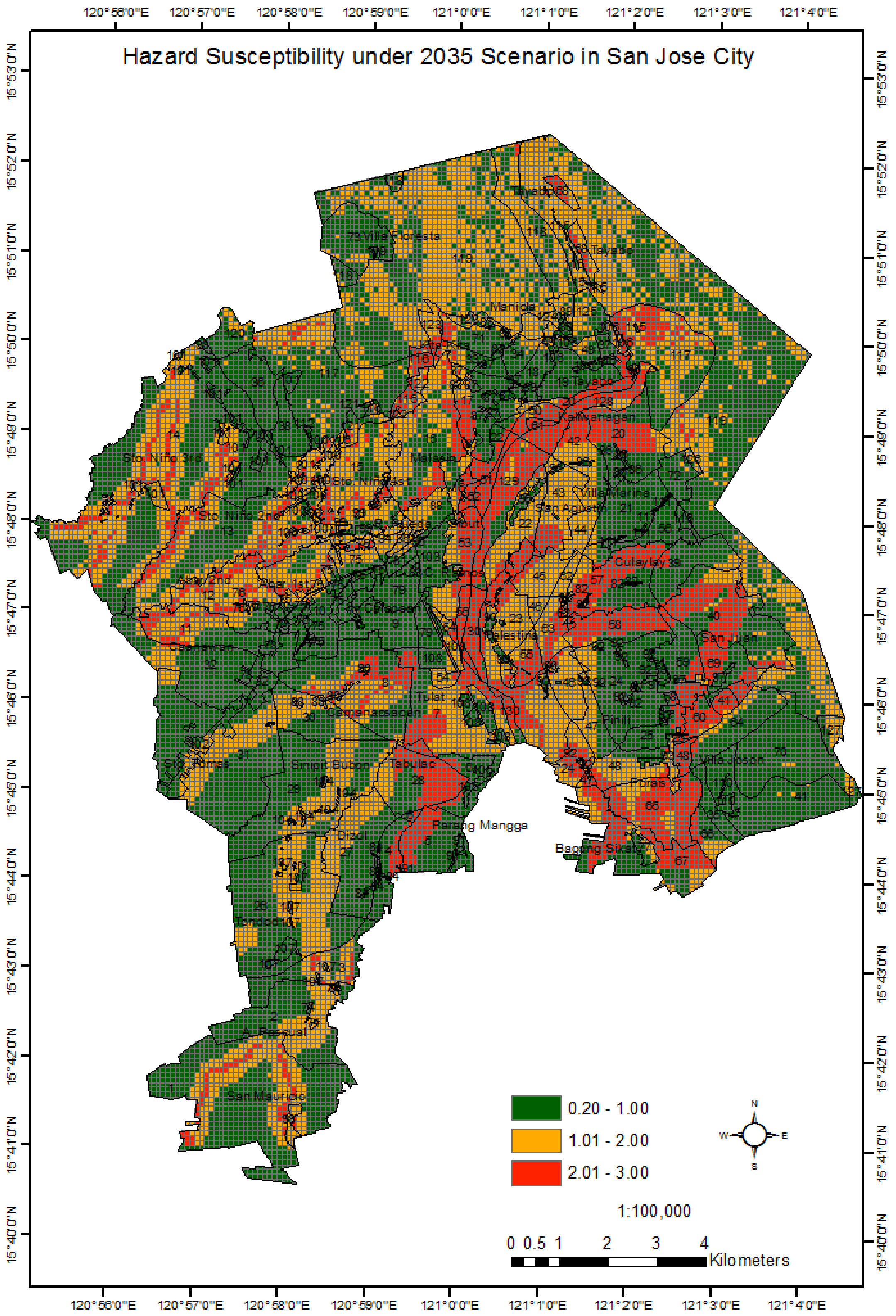


Figure 3. Hazard susceptibility under 2035 scenario in San Jose City

The study revealed that Barangay Abar ranked highest in terms of exposure index score. Areas in barangays surrounding the Poblacion and urban barangays had exposure index scores ranging from 3.01 to 4.0, whereas areas with considerable distance from these barangays had scores ranging from 2.01 to 3.0. In general, the city had a mean exposure index score of 2.74 and a median of 3.13 (Fig. 4).

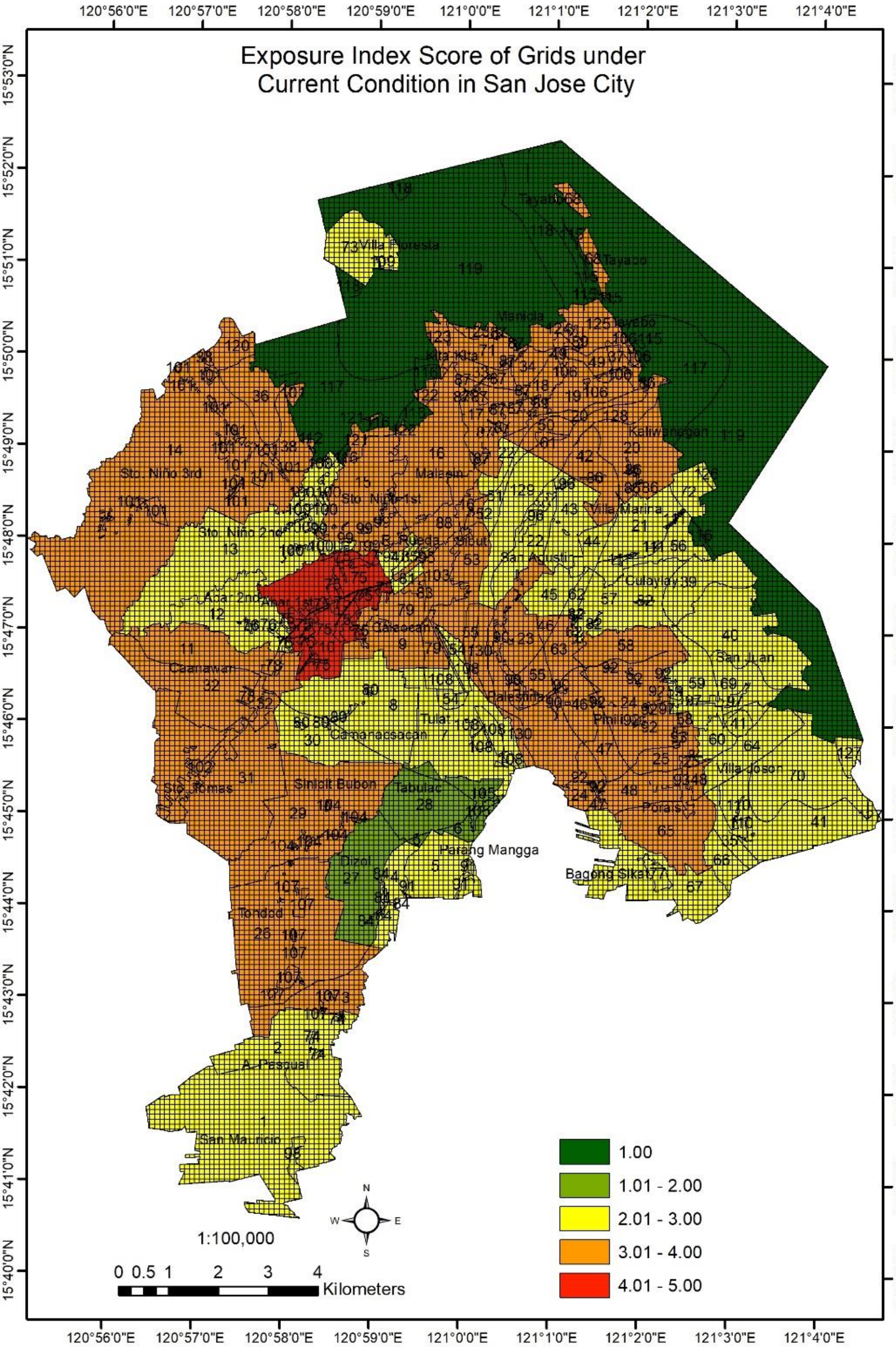


Figure 4. Exposure index score under the current condition in San Jose City

Some 73 percent of the barangays of San Jose City had susceptibility index scores ranging from 4.01 to 5.0 and the rest have scores ranging from 3.01 to 4.0, yielding a mean susceptibility index score of 3.69 and a median of 4.29 (Fig. 5).

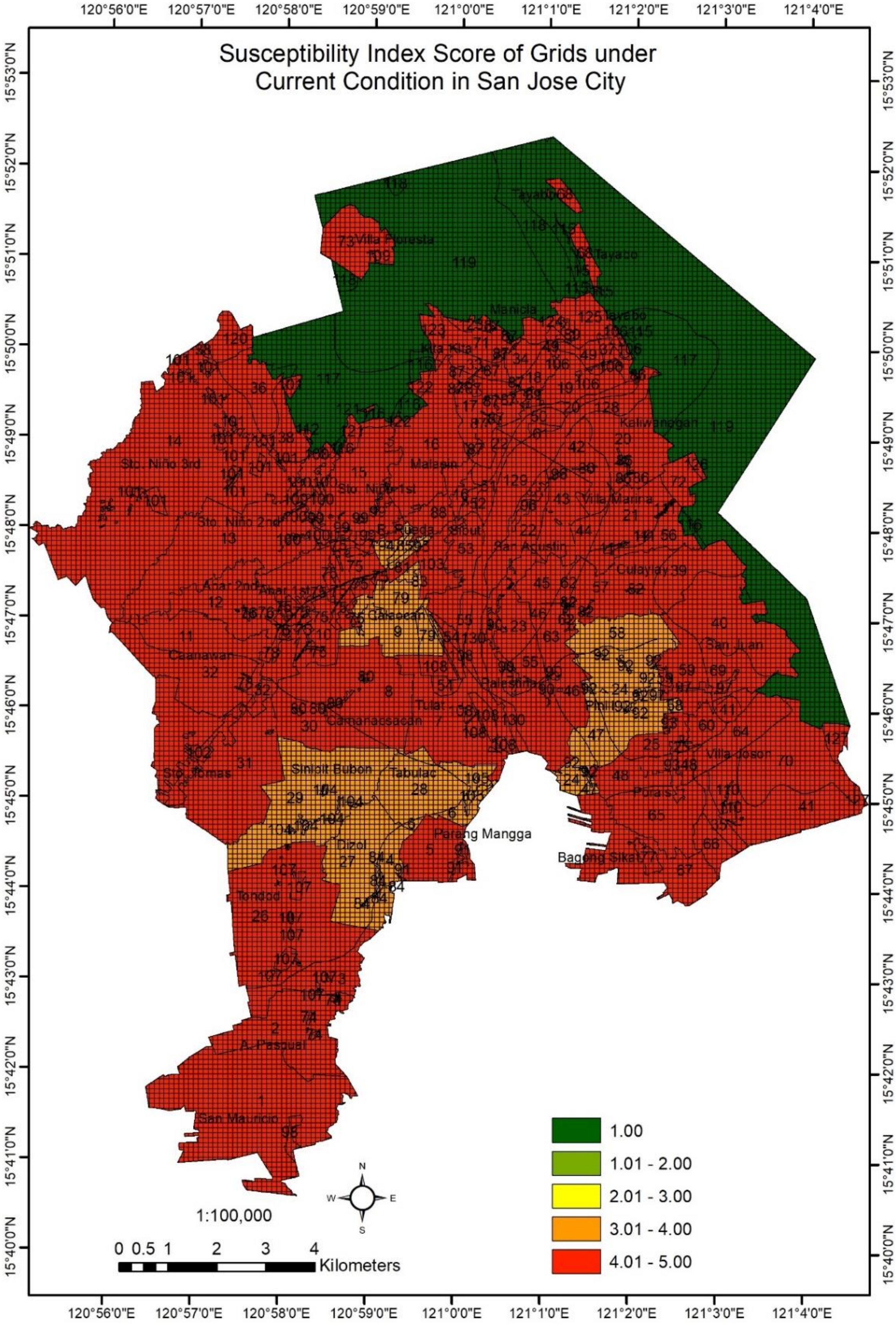


Figure 5. Susceptibility index score under current condition in San Jose City

A substantial area in Barangay Sibut ranked lowest in terms of lack of adaptive capacity index score among the barangays of the city. Areas in Barangays San Mauricio, A. Pascual, Parang Mangga, Sinipit Bubon, Tabulac, Tulat, Villa Joson, Sto. Nino 2nd, San Agustin, Villa Marina, and Villa Floresta garnered ratings ranging from 3.01 to 4.0. The rest of the barangays garnered index scores ranging from 2.01 to 3.0 (Fig. 6).

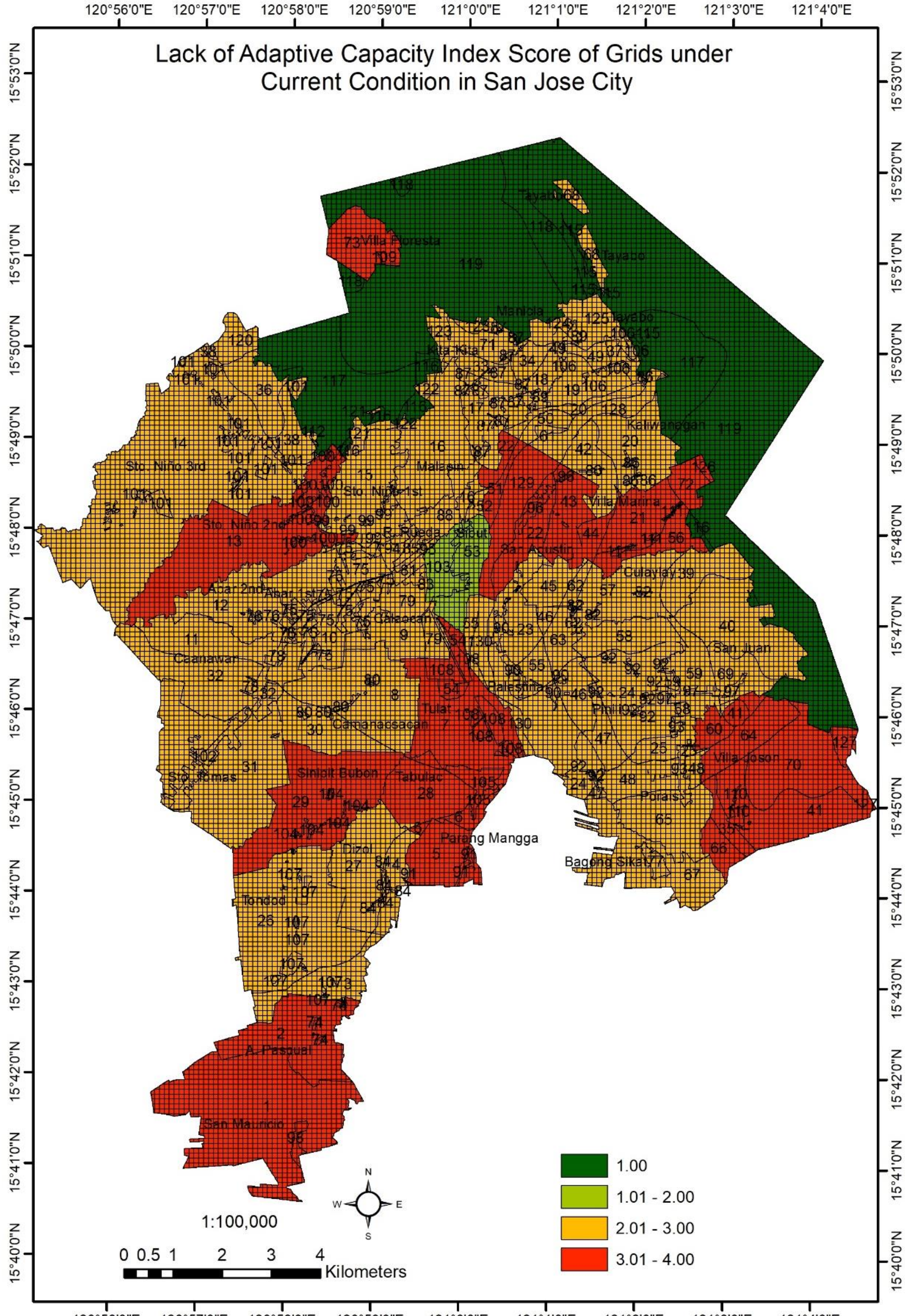


Figure 6. Lack of adpative capacity index score under current condition in San Jose City

The mean lack of adaptive capacity index score of San Jose City was computed at 2.52 and the median was 3.00. Overall, the least vulnerable areas are in Barangays R. Rueda, F.E. Marcos, Tabulac, and Dizol. (Fig. 7).

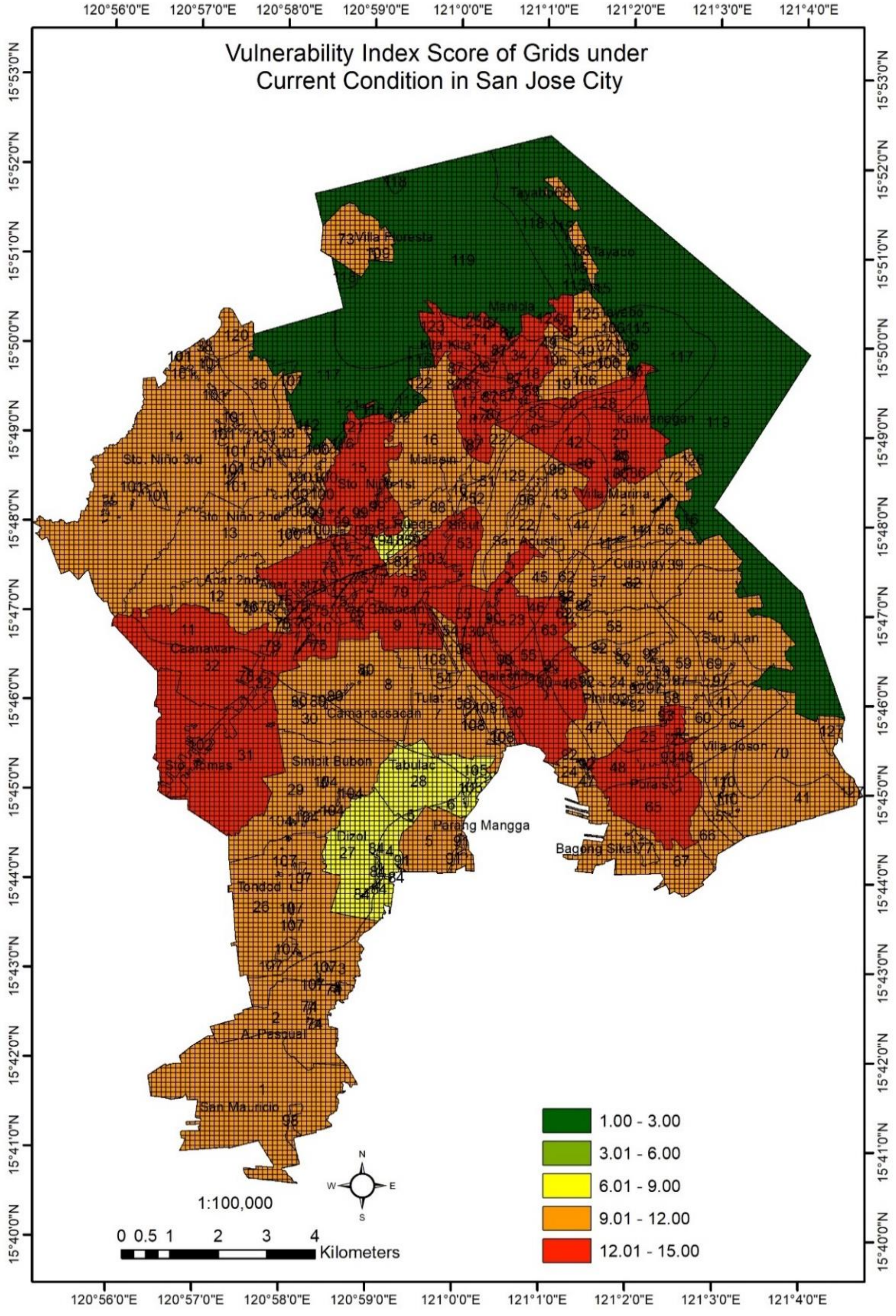


Figure 7. Vulnerability index score under current condition in San Jose City

The city received a mean risk index of 12.98 which was considered low relative to the highest possible score of 75 (Fig. 8).

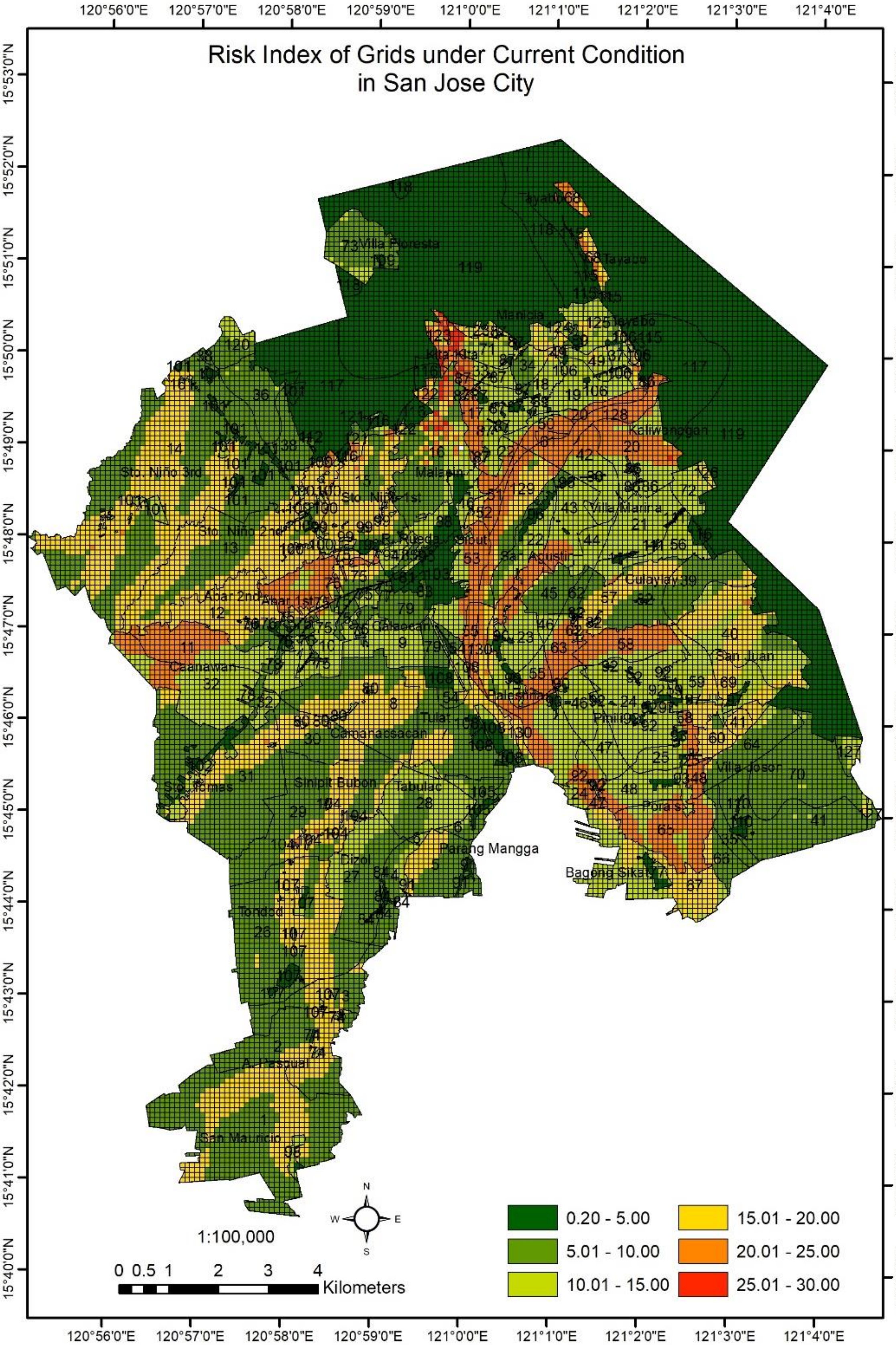


Figure 8. Risk index under the current condition in San Jose City

With the assumption that vulnerability index scores are constant, increased scores of hazard susceptibility in most of the areas consequently increased the risk index of the city under extreme event scenarios. The average risk index was 15.6 (Fig. 9).

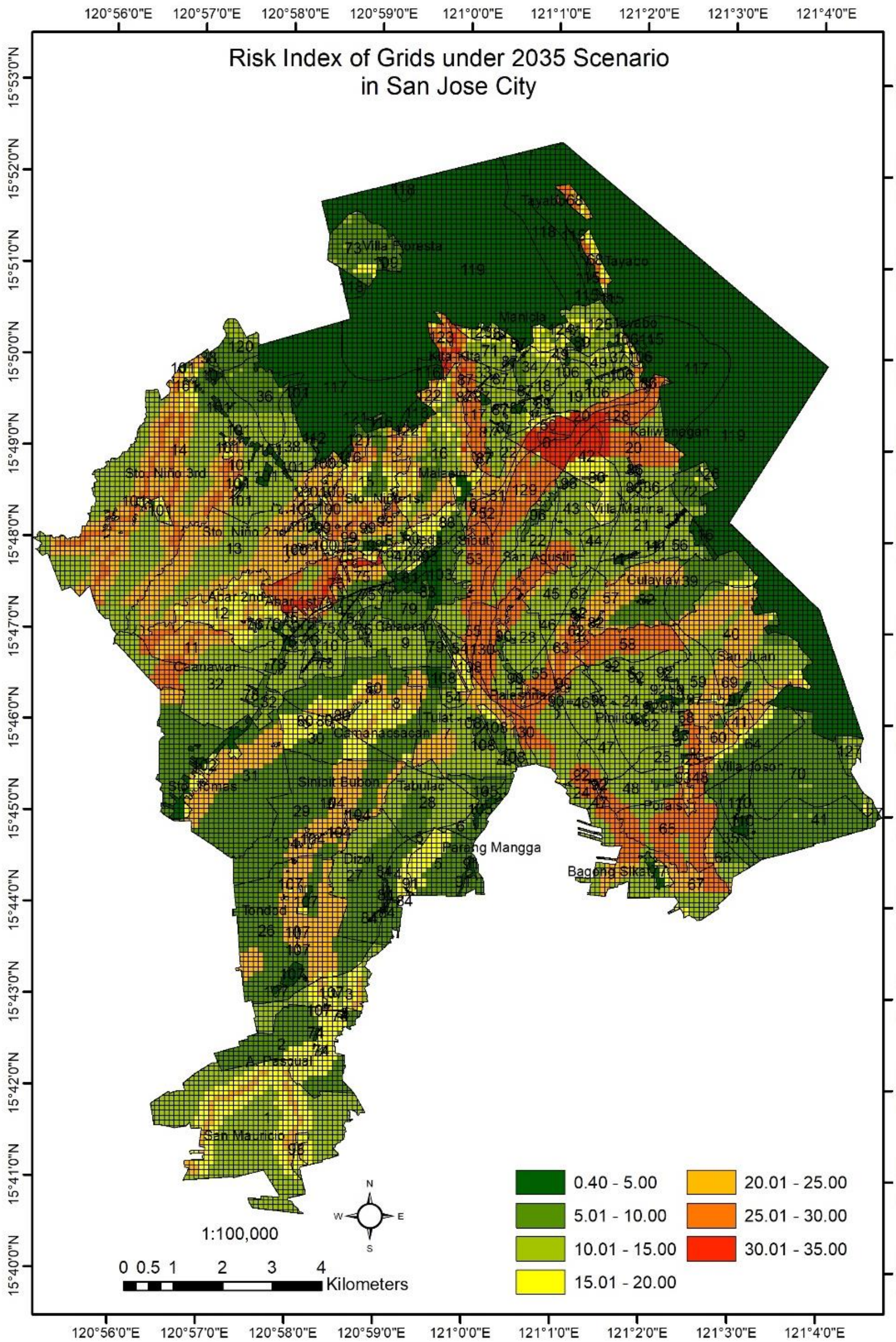


Figure 9. Risk index score under 2035 scenario in San Jose City

Modeling equations were formulated corresponding to each objective function (Table 2) which were subjected to constraints on resources and targets (demand for commodities).

Table 2. Area planted, total yield and demand for crops in San Jose City, 2015

| Objective Function | Optimization | Equation |
|---|---|---|
| Total tomato production by maximizing tomato suitability | Max = | Σyta (grid) * x_t(grid) * p_t(grid) |
| Total bitter melon production by maximizing bitter melon suitability | Max = | Σyaa (grid) * x_a(grid) * p_a(grid) |
| Total rice production by maximizing rice suitability | Max = | Σyra (grid) * x_r(grid) * p_r(grid) |
| Total onion production by maximizing onion suitability | Max = | Σyoa (grid) * x_o(grid) * p_o(grid) |
| Total average disaster risk of the city | Min = | Σh(grid) * v(grid) * x_h(grid) |
| Total suitable residential area | Max = | Σp_h(grid) * x_h(grid) |

Under the current condition, the city will have an annual tomato production of 268,292 MT using a total land area of 4,895 ha with the land use resulting from running all the goals (Fig. 10).

The city would have a bitter melon production of 155,814 MT per year. Using a total land area of 5.19 ha, the city can exceed the current bitter melon production, but not the demand of the city populace. In terms of rice production, the city can still meet its current production of 88,279 MT and overproduce for the city populace despite the smaller land area to be used for rice production. The current onion production can be met by the city using the recommended land area of 472 ha, smaller by 508 ha than the current land area.

The current average risk of the entire city was minimized to 0.53. The model provided a solution allocating the residential areas where they are most needed, specifically in grids under Barangays Sto. Niño 1st and Malasin, concomitantly providing for the additional population of 10,725 based on the 2020 projection. The total land area assigned by the MGLP for residential areas was 567.87 ha.

All the grids in the land area to be managed were assigned with specific land use type, hence the total land area of 12,991.43 ha would be used.

Under the 2035 scenario, with the land use options processed by MGLP (Fig. 11), tomato production would decrease by 26,116 MT, but still surpassing the target of 337 MT in 2035. Bitter melon production would increase from 155 MT/year under the current condition to 192 MT/year. Even with the increase in targets, rice and onion productions can still meet the targets in 2035.

The average disaster risk index of the city was reduced to 1.45. The residential area would cover 970.05 ha, which is more than enough for the additional populace of 48,044 (Table 3).

Table 3 Optimization runs results pursuing Goals 1-8 under current and 2035 scenarios in San Jose City

| Optimization Run Results | | Unit | Current Condition | | 2035 Scenario | |
|---|---|---|---|---|---|---|
| | | | TL | OAL | TL | OAL |
| 1 | Total tomato production | MT | 332 | 268,293 | 337 | 242,177 |
| 2 | Total bitter melon production | MT | 154 | 156 | 156 | 192 |
| 3 | Total rice production | MT | 88,279 | 88,279 | 89,572 | 89,572 |
| 4 | Total onion production | MT | 10,018 | 10,018 | 10,164 | 10,164 |
| 5 | Total average disaster risk | MT | 12.98 | 0.53 | 15.60 | 1.45 |
| 6 | Total suitable residential area | ha | 78.53 | 567.87 | 351.78 | 970.05 |

TL – Target Level OAL – Optimal Achievement Level

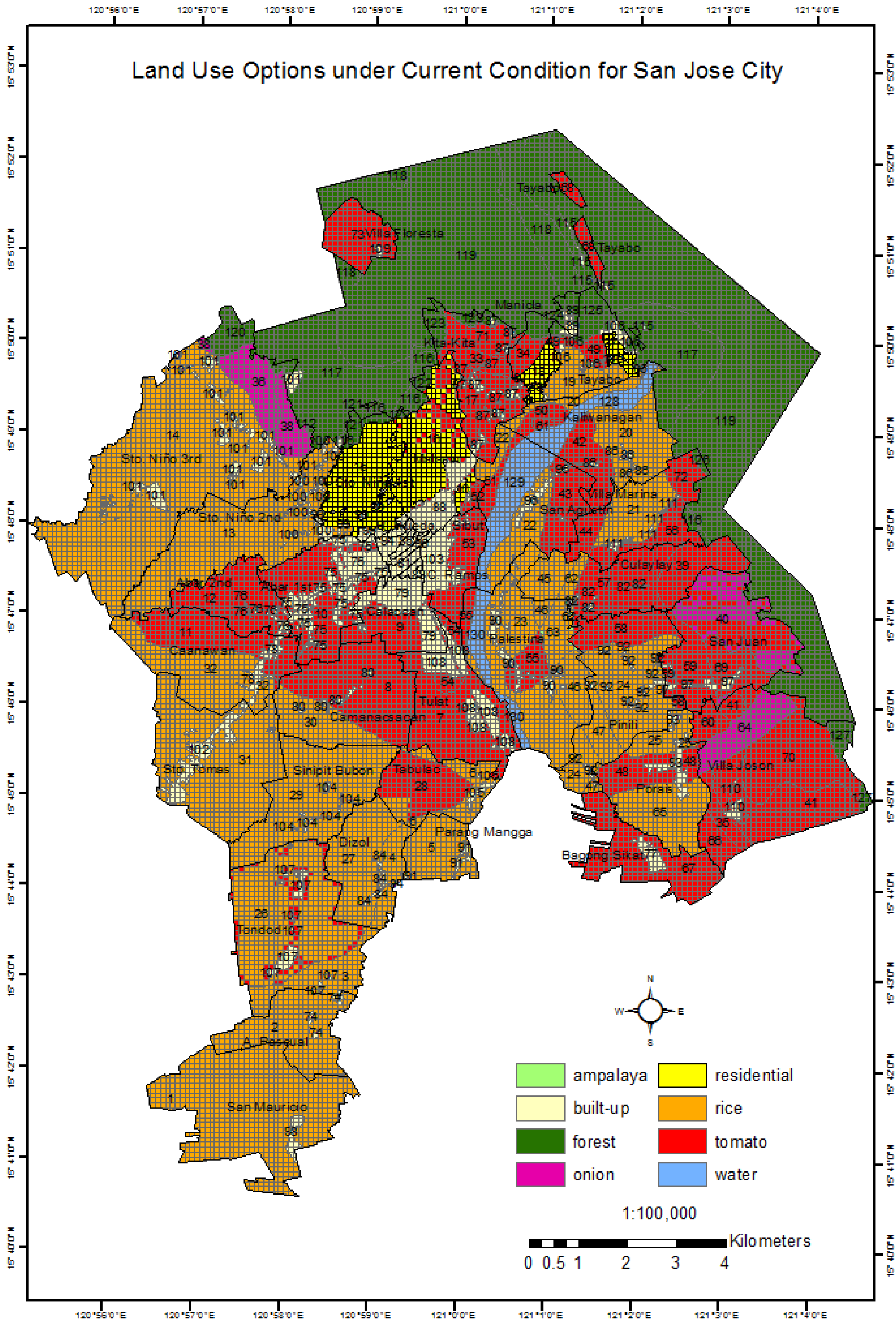


Figure 10. Land use options pursuing Goals 1-8 under current condition for San Jose City

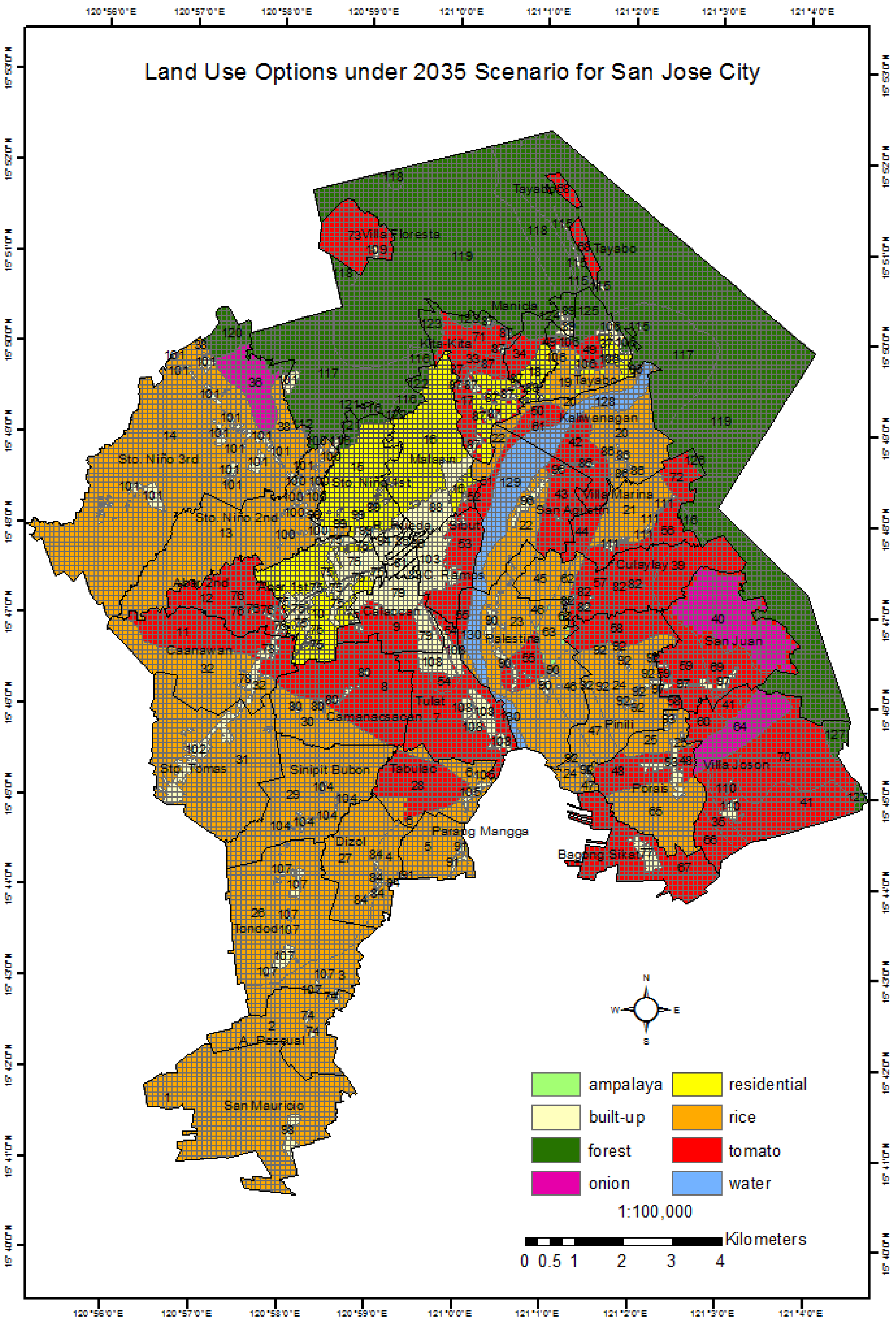


Figure 11. Land use options pursuing Goals 1-8 under 2035 Scenario for San Jose City

## 4. Discussion

Based on the total yield given by the CAO, rice, and onion produced in the locality exceeds the local demand. However, given the 15-ha area planted allotted for a tomato with a total yield of 180 MT, tomato being produced in the locality is inadequate to meet local demands. With an even smaller area of 8.25 ha for bitter melon production, the total yield of 28 MT in the city cannot meet its demand of 329 MT per annum.

Aside from issues on land area allocation for tomato production, farmers also mentioned that yield was affected by typhoons and pests. The majority (73 percent) of respondents that plant tomatoes were affected by insects and worms, like aphids and thrips. In terms of net income, tomato production had the highest average of PhP 600,048.54 per year.

A flood susceptibility map was generated using the raster calculator of GIS. LGU officials gave flooding the highest rating of 0.4 (1 being the highest) among four natural hazards as the city is prone to flooding, in terms of its frequency, scope, and impact.

Grids rated as moderately susceptible in the current condition and highly susceptible in 2035 scenario to flooding generally followed the meandering of the river. Low-lying areas and flood plains of the city which follow the meander of the river channels experience seasonal flood events when the Talavera River, a major river, overflows.

River terraces are exhibited by almost flat to gently sloping ground surface and are mostly utilized as residential and agricultural areas of the city (DENR-MGB III, 2012).

Aside from the river’s natural characteristics of being wide, braided, and shallow, its riverbanks are unstable and have highly erosive banks leading to heavy sedimentation. Heavy rainfall and extreme events are also major contributors to massive sedimentation in river channel and to its widening.

Agricultural drought, as a hazard, was rated with 0.2 by LGU officials. The right and left sides adjacent to Talavera River were rated with high susceptibility to agricultural drought under normal conditions.

The high susceptibility to drought of peripheries of the Talavera River was attributed to low rainfall and high temperature of the area under normal conditions.

During extreme events, i.e., reduced rainfall and increased temperature, areas highly susceptible to drought increased by 43 percent from the normal condition. A study was conducted on the effects of drought on rice production in Nueva Ecija in 2009. It was found out that in 1998, an El Niño year, there was a significant drop in rice production, which gradually increased after that (Geoinformatics Center, 2017).

The mountainous areas of the city were also found to have moderately high to very high susceptibility to both rain-induced and earthquake-induced landslides (DENR-MGB III, 2012) and are characterized by highly fractured and moderately to highly weathered rocks. Inter-valley creeks are short with steep slope gradients. Below are alluvial fans where stream velocity slackens and sediments deposit. Rivers tend to shift channel courses.

REDAS was used to generate the level of impacts that may result from an 8-year and 23-year return period earthquake. Areas affected by earthquakes can be attributed to the Philippine fault line passing through the structural valley of the city and cutting across other municipalities, such as Carranglan, Rizal, Bongabon, Laur, and Gabaldon. The Philippine fault line and the structural valley come into contact with the northern and southern Sierra Madre rock units (DENR-MGB III, 2012).

The hazard map of the city reveals that the low-lying areas generally had no susceptibility to any hazard. However, areas along the river network of the city received moderate susceptibility under normal conditions and high susceptibility under extreme events scenario. Such results can be attributed to the higher weight placed on flooding relative to the other three natural hazards.

Meanwhile, the overall moderate susceptibility of the grids in the mountainous part of the city was due to a combination of high susceptibility to flooding and landslide.

Two barangays with the least vulnerability were Barangays R. Rueda and F.E. Marcos, both found in the Poblacion area. Although there was high population density, the absence of agricultural area made their exposure index score low. Moreover, Poblacion barangays also had low susceptibility and high adaptive capacity because of better access to water, health and nutrition, and education services. On the other hand, the two rural barangays, Barangays Tabulac and Dizol, had also a low vulnerability index because of a very low exposure index due to low population density.

Most grids with the highest risk were in mountainous barangays because of high hazard and high vulnerability index scores. Although a moderate hazard index score was observed, Barangay Abar 1st got a very high exposure index score due to being densely populated, thus receiving a higher risk index. Other grids had relatively high risk because of their moderate hazard and high susceptibility index scores. Grids which received the highest risk score under normal condition were also among the top scorers under 2035 scenarios. Given that there would still be no people in the mountainous part of the city, even if hazard susceptibility scores of grids are quite high, still the risk would be low.

Foden's framework of analysis illustrates that grids classified in high latent risk or currently not at risk are due to low exposure levels. Barangay C. Ramos was also on the list because of the absence of an agricultural area in the Poblacion area. Monitoring the environment for concealed risk is the appropriate intervention.

Barangays classified as having the greatest risk or highly vulnerable were those with high susceptibility levels but with moderate exposure and lack of adaptive capacity levels. Barangay C. Ramos may have a high vulnerability index score (9.71), but it was classified as having high latent risk because of low exposure levels.

Grids in Barangay Abar 1st received the highest vulnerability score (14.63) because of high exposure and susceptibility levels. Further research studies should be conducted on how to minimize susceptibility, both economically (poverty incidence) and physically (utilities and public infrastructure).

Development goals were translated into six prioritized objective functions. Objective functions 1 to 4 pertained to the city's goal of developing agriculture as a reliable economic linkage to industry and ensuring optimization of land use in the city. Maximizing tomato production was placed first because of underproduction despite being high income generating.

Priority 5 is minimizing disaster risk to regard the impacts of natural hazards to people, the most important element at risk of the city. Interlinked with this is Priority 7, i.e., maximizing residential suitability to provide healthy and safe settlements to the additional populace and those living in an unsafe environment.

Optimization run results imply that tomato production of the city can exceed its current demand entailing a larger area of production. Bitter melon production, on the other hand, can also attain its current production in a smaller area. Even planted in smaller areas, the city may still perform its role as rice and onion producers of the country.

The MGLP assigned residential use to grids where they are most needed due to higher population density and with minimal disaster risk. Disaster risk reduction was evident in the allocation and locating of the most suitable residential areas based on the risk index.

Decision makers in the local government of San Jose City were provided with land use allocation options that are optimal because they are based on scientific information and quantified parameters.

## 5. Conclusions and Recommendations

The methodological framework of mainstreaming DRR in the CLUP of a local government unit may be data-intensive but doable. It is highly recommended that the methodology be adopted by all LGUs based on the premise that what one can measure, one can manage.

Disaster risk assessment should be conducted first so that projects, programs, and policies on DRR will be appropriate. For an area such as a city, different sites have different hazard susceptibility levels attributed to its nature of being site-specific, thus require specific adaptation approaches. Vulnerability assessment is an excellent basis for prioritizing projects that have implications on economic and social development. The resiliency of the community will ultimately be achieved when disaster risk is reduced through optimal land use allocation.

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