Application of Geographical Information Systems (GIS) for Mapping Food Vulnerability in Denpasar, Bali.

I Ketut Sardiana
Faculty of Agriculture, Universitas Udayana, Bali, Indonesia

e-mail: ketutsardiana@unud.ac.id

Abstract. This study aims to map food vulnerability through geographic information system applications in the city of Denpasar. The research method is descriptive quantitative. The data collected consisted of spatial data in the form of administrative maps with the sub-district as the mapping unit, and attribute data consisted of indicators of food vulnerability based on approach of the food and nutrition surveillance system (FNSS) consisting of: agriculture (food availability), health (energy preference), and socioeconomic (poverty). Each indicator is scorched, the combination of these three indicators produces a composite value for the FNSS which indicates the level of food vulnerability in an area. The results showed that in all sub-districts in Denpasar City were classified as high-risk areas, characterized by indicators of high deficit serelia food production (\( r < 0.95 \)), indicators of malnutrition and deficiency (underweight) is classified as safe (\(<15\%\)) and indicators of food utilization are classified as safe (pre-PF and PF-I \(<20\%\)).

1. Introduction

Food is an essential requirement for human life, because food other than very necessary for the fulfillment of psychological needs, food can also form human resources as an asset for nation and state development. Food problems will be a trigger for food vulnerability and nutritional problems. Food vulnerability is a condition of food inadequacy experienced by regions, communities, or households, at any given time to meet the standard physiological needs for growth and public health. Food insecurity can occur repeatedly at certain times (chronic), and may also occur due to emergencies such as natural disasters or social disasters (transients). The condition of food vulnerability can be caused by: (a) the absence of economic access for individuals / households to obtain adequate food; (b) the absence of physical access for individual households to obtain adequate food; (c) insufficient food for the productive life of individuals / households; (d) insufficient food fulfillment in quantity, quality, variety, security and affordability. Food insecurity is strongly influenced by people's purchasing power determined by income level. Low levels of income exacerbate energy and protein consumption. Problems of food vulnerability will occur throughout human life, it is necessary to find the concepts of effective and efficient handling according to the situation and conditions. One such concept is the Food and Nutrition Surveillance System (FNSS). Food and Nutrition Surveillance System (FNSS) is a series of activities of observing food and nutrition situation through provision of data / information, data processing and analysis and intervention plan for handling food and nutritional problems.

City of Denpasar in Bali Province is a region with high population density which faces problems in food vulnerability related with food availability, food security, and high number of pre-prosperous families, thus having less access to meet food needs. Efforts to control that can be done is to consistently
administer the food security and vulnerability conditions from time to time, so as to formulate an adequate database for tactical policy making in food security and vulnerability efforts. The database is linked to territorial conditions that include the components of food availability, food security, and pre-prosperous families.

Improving the performance of the information systems of food vulnerability requires the development of computer-based information systems with a spatial approach by creating software that can be specifically used to facilitate data input, processing and data analysis, reporting of results of food security and vulnerability monitoring activities more fully and quickly, and presentation of data on regional mapping based on vulnerability indicators. In order that regional related information can be managed properly it can be done with Geographic Information System (GIS) (Hartono, et al., 2005).

The existence of Geographic Information System (GIS) technology has made it easy for many people to manage and use spatial data (geographic referenced data) (Jumadi and Sigit Widiadi, 2009). The advantages of developing computer-based information system with this geographical approach can be presented data food vulnerability in the form of maps that are more easily understood and more informative so as to facilitate the implementation of activity evaluation and intervention planning adjusted to the condition of the region.

Geographic Information System can be used to decide policies based on population data on food and nutrition awareness applications. Furthermore, based on the information system we can draw information from the maps available in the GIS application, or contrarily, obtain information on which particular region map will appear, if we use certain information as the search criteria, so that decision making will be easier and right on target.

This GIS-based information system strongly supports the activities of food vulnerability monitoring to be better especially in terms of processing, data analysis, data presentation and reporting to be easier, faster, complete and timely and in accordance with the conditions of each region. Thus all decision-making related to the policy of handling food vulnerability becomes faster and more precise.

The purpose of this research is to develop GIS application to support the mapping of food vulnerability activities, while the benefit is with the application of GIS on the mapping of food vulnerability is expected to minimize data processing mistakes and delay of reporting, so that problems related to food problem can minimized, interventions conducted in accordance with appropriate conditions and targets so that handling of food vulnerability in a region in the future become more optimal.

2. Methods

2.1. Study area

The study was conducted in Denpasar, Bali Province. The research methods were survey and secondary data analysis. The collected data consisted of spatial data and attribute data. The spatial data was administration map with subdistrict area as the mapping unit, consisting of South Denpasar (49.99 km²), East Denpasar (22.31 km²), West Denpasar (24.06 km²), and North Denpasar Subdistricts (31.42 km²). Research site shown on Figure 1.
The attribute data consisted of food vulnerability indicators. The indicators used by Food and Nutrition Surveillance System (FNSS)) approach were: agriculture (food availability); health (energy preference); social economy (poverty due to prosperity and pre-prosperity).

1. Agriculture Indicator, expressed by the ratio of serelia production to consumption in the region.
\[
r = \frac{\text{rice availability}}{\text{rice need}}
\]

Wich:
- rice availability = grain dry milled yield converted into rice 85% x total production
- rice need = average consumption /capita x population in ½ year divided by 1.000

2. Health indicator, express it by the percentage of babies with malnutrition to the total number of babies in the area.
\[
\text{Prev. malnutrition (\%)} = 1 + \frac{(n_{\text{malnutrition} < -2 \text{SD}})}{(n_{\text{infant collected}})} \times 100\%
\]

Nutritional status of infants is categorized into 3 nutritional statuses, which are:
1) Malnourished: less than minus 3 of standard deviation (<-3 SD);
2) Undernourished: between minus 3 of SD and minus 2 of SD
3) Good nutrition: over minus 2 of SD

3. Social economic indicator, expressed by the percentage of pre-prosperous and prosperous-1 families in the area:
\[
\% = \frac{\text{pre-PF + PF-1}}{\text{total families}} \times 100\%
\]

which:
- PF = prosperous family
The criteria to categorize families into poverty status were: 1) Pre-prosperous family (pre-PF): if not meeting one of the requirements for prosperous family; 2) Prosperous family (PF): if able to fulfill basic needs minimally. Then, the balance was scored:

1) Score 1: if ratio > 1.14 (surplus)
2) Score 2: if ratio 1.00 – 1.14 (self-sufficient)
3) Score 3: if ratio 0.95 – 1.00 (sufficient)
4) Score 4: if ratio less than or equal to 0.95 (deficit).

Vulnerability level based on the sum of scores of the three indicators, i.e. food, nutrition, and poverty, and can be classified into 3 risk areas, i.e. high risk area (score 9 – 12), medium risk area (score 6-8) and mild risk area (score 3 -5). High risk area can happen if one of the indicators has a score of 4 although the total score of the three indicators is less than 9.

The data of food availability, energy preference and poverty was then analyzed by Geographic Information System of QGIS software version 3.16. to get cluster/zonation of food security and vulnerability levels. The study results are presented in the food security and vulnerability maps of Denpasar.

3. Result and Discussion

Food vulnerability situation is described in Food and Nutrition Surveillance System (FNSS) which is a system of continuous detection and management of information on food and nutrition situations. The resulted information is the basis of policy planning, program coordination and food and nutrition vulnerability countermeasure. The indicators were food availability for agriculture, food access for health and food utilization for social economy. Data processing produced FNSS composite index values which was converted into FNSS map in Figure 1.

Figure 1 shows that overall FNSS condition in Denpasar in all subdistricts is red, meaning all areas were vulnerable. It was because the score of production indicator was 4 in all subdistricts, meaning high deficit. It meant production in Denpasar couldn’t comply the consumption needs of people of Denpasar. It showed that the availability policy of food security wasn’t production policy but other policies, including price and supply stabilizations. Paddy production data and population in Denpasar are presented in Table 1.

### Table 1. Rice production and total population of Denpasar city in 2017.

| Kecamatan | (A) | (B) | rn | ra (ton/year) | r | classification |
|-----------|-----|-----|----|--------------|---|----------------|
| Densel    | 114 | 143030 | 16,305.42 | 8.716.5 | 0.53 | deficit |
| Dentim    | 114 | 76740  | 8,748.36  | 7.942.9  | 0.91 | deficit |
| Denbar    | 114 | 129895 | 14,808.03 | 5.682.6  | 0.38 | deficit |
| Denut     | 114 | 98985  | 11,284.29 | 8.663.08 | 0.77 | deficit |
| Denpasar  | 448650 | 51,146.10 | 31.005 | 0.61 | |

Keterangan: (A) = average consumption per capita; (B) = population in ½ year; ra = rice availability; rn = rice need; r = ratio availability : need rice

However, efforts to increase food material production should still be performed to reduce dependence on food materials from other regions. Possible efforts were reducing the rate of conversion of agricultural land into non-agricultural land, agricultural business intensification to increase productivity and utilization of fallow lands for crop agricultural businesses.
Figure 2. Map of FNSS Composite Index of Denpasar

Figure 3. Ratio of normative consumption per capita on net cereals production

Malnutrition and underweight indicators can be seen in Figure 3.3. Of 10,988 infants weighed in 2015, 20 infants or 0.18% were malnourished and 207 infants or 1.88% were underweight. The figure shows that all four subdistricts in Denpasar were safe, meaning the percentages of malnourished and underweight infants were less than 15%. The percentages of malnourished and undernourished infants in the subdistrict in Denpasar are: 3.06% in West Denpasar Subdistrict, 3.04% in East Denpasar Subdistrict, 0.89% in South Denpasar Subdistrict and 1.45% in North Denpasar Subdistrict. However, considering the importance of maintaining nutritional status for the growth and development of infants, parents should pay attention to thing which can prevent nutritional issues, especially for those who have vulnerable nutritional status.
Food utilization indicator based on data of pre-prosperous and prosperous-1 families can be seen in map 3.4. The map shows that all subdistricts in Denpasar were safe (green) or had percentages of pre-prosperous and prosperous-1 families < 20%. The percentages of pre-prosperous and prosperous-1 families of the subdistricts in Denpasar were: 1,041 households in West Denpasar Subdistrict (1,41 %), 339 households in East Denpasar Subdistrict (1,53%), 614 households in South Denpasar Subdistrict (0,87 %) and 1,207 households in North Denpasar Subdistrict (2,44%). Very low percentages of pre-prosperous and prosperous-1 families (< 20 %) don’t mean the City Government of Denpasar can ignore poverty reduction programs. They should keep trying to reduce poverty rate, even eliminating pre-prosperous and prosperous-1 families in Denpasar if possible. Therefore the government should make related policies on methods to reduce the numbers of pre-prosperous and prosperous-1 families systematically and sustainably.

Conclusion
The Food and Nutrition Surveillance System (FNSS) on cereals food production indicators in all subdistricts in Denpasar showed that it was a highly deficit area (production: needs ratio <0.95); The indicators of malnutrition and underweight of four sub-districts in Denpasar showed that they were safe, meaning the percentages were less than 15%. The food utilization indicators based on pre-prosperous and prosperous-1 families data showed that all sub-districts in Denpasar were safe, or had <20% pre-PF and PF1 percentages. The level of food insecurity in Denpasar City is classified as high risk because the cumulative value of the three indicators of food insecurity reaches 6 and there is an indicator with a value of 3.

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