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Carrying Capacity Based on Environmental Services for Food Supply in Talaga City

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Abstract: Environmental Carrying Capacity (ECC) for food supply is the ability of the environment to support population activities through a comparison between the need and availability of food energy. This research aims to provide initial data related to the spatial distribution of ECC for food supply in Talaga Jaya, Telaga, Telaga Biru and Tilango Sub-Districts as part of the city of Talaga and the general conditions of their status descriptions. The Environmental Service Performance Index (ESPI) of the parameters of Landscape, Natural Vegetation and Land Cover was used as a factor in distributing the availability of food energy. Land class and roads distributed population density and food energy needs. The results of the research were analyzed spatially using a supply-demand approach on a grid scale of 0.1 km x 0.1 km. The results found that the spatial distribution of ECC for food supply was in deficit status of 20.03 km² (11.11%), balanced at 120.86 km² (67.02%) and surplus at 39.45 km² (21.88%). Descriptively, the deficit area cannot be covered by the surplus area if there is an energy flow because the high food energy requirement is 64.7 billion kcal/year, while the availability of food energy is only 51.4 billion kcal/year. Thus, the research area has passed the peak of its population growth and is only able to meet the food energy demand for 79.4% of its population. In this case, the government can promote agricultural commodity intensification and diversification policies to meet domestic food energy needs.

Keywords: ECC; Food supply; Spatial distribution; Supply-demand approach; Talaga City

Introduction

Along with the development and construction in various sectors that require the allocation of natural resources in an exploitative manner, followed by increasing population growth, the capacity and quality of the environment is being threatened (Ekawaty et al., 2018; Febriarta & Oktama, 2020). Spatial phenomena such as urbanization and conversion of agricultural and forest land are serious threats that if not prepared with careful planning will threaten ecological health. The phenomenon of urbanization can increase pressure on land and trigger land conversion, especially for domestic activities (Nurdin, 2011). As a reflection, between 2005-2015 at least 2,208 ha of rice fields and 10,865 ha of dry fields/fields in Gorontalo Regency have been converted into non-agricultural land. Without any prohibition and policy restrictions on the conversion of rice fields by the local government, it is predicted that the decline in rice fields will continue and decrease by 3,706 ha in 2035 (Subandi et al., 2019).

Talaga Jaya, Telaga, Telaga Biru and Tilango Sub-Districts are one of the important areas in Gorontalo Regency as the center of economy, social and culture. Based on the Rencana Tata Ruang dan Wilayah document of Gorontalo Regency 2012-2032, these four

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sub-districts are included in protected areas and cultivation areas as well as being directed as strategic areas in terms of economy, socio-culture and environmental support functions (Perda No. 4/2013). Its strategic location as an urban fringe and passed by the Trans Sulawesi Road and Gorontalo Outer Ring Road (GORR) makes economic and social activities in this area quite lively. Furthermore, these four sub-districts are projected to become the New Autonomous Region (DOB) of Talaga City which is marked by the Decree of the Governor of Gorontalo Number 416/1/XI/2021 concerning the Approval of the Establishment of the New Autonomous Region of Gorontalo Province. This has encouraged more adjustment efforts in development in various sectors so that it has an impact on accelerating spatial, economic and social transformation.

Talaga Jaya, Telaga, Telaga Biru and Tilango sub-districts as candidate new autonomous regions namely Talaga City, need to be evaluated for their environmental carrying capacity because every development has an ecological impact as is generally the case in spatial concentration centers (Brașoveanu, 2023). One of sectors that has the potential to be impacted by the dynamics of regional development and urbanization is the weakening of food security (Tono et al., 2023; Wang, 2022). Food as a type of environmental service is the axis for all domestic activities, industry and even political power (Ichijo & Ranta, 2016; MEA, 2005; UU No. 18/2012). However, currently the problem of food security has become an issue that has received serious attention from the local government. Recapitulation data from BPS Kabupaten Gorontalo (2020) shows that the value and production of agriculture in these four sub-districts tend to decline during the 2013-2019 period and are predicted to continue to be in deficit considering the ongoing conversion of agricultural land for settlements. Although this area is planned to be made a new autonomous region with city administrative status so that it is no longer directed to become a food production base, a proper understanding of the capacity of the Environmental Carrying Capacity for food supply is still needed in order to formulate policies for the utilization and management of food resources in relation to population control and the regulation of the distribution of activity centers. Thus, efficiency and productivity, equity, balance and justice, and the sustainability of resource distribution can be achieved (KLH, 2014; Rustiadi et al., 2009).

Various studies on food security have previously been conducted across Gorontalo Regency and Gorontalo Province using non-spatial methods and approaches. Consequently, this study aims to address the gap in research regarding spatially-based regional food security. It emphasizes the natural conditions of the study area in supporting population food security at a detailed scale, thereby offering a more representative perspective for regional planning. Through this method, regional food security can be assessed, and capacity thresholds identified—particularly regarding emergency situations such as natural disasters and/or pandemics—enabling accurate and measurable mitigation efforts.

Method

Research Location

The research area includes Talaga Jaya, Telaga, Telaga Biru and Tilango Sub-Districts. This area was chosen because there is talk of developing it into Talaga City. Astronomically, the four sub-districts are located between 0.547 N – 0.803 N and 123.002 E – 123.08 E. The tools used in this research include hardware and software devices, while the types of data used consist of spatial and tabular data. Information about the data is described in Table 1 below.

Table 1. Classification of Data Types and Sources

Data	Type	Sources
Environmental Service Performance Index for foods supply	Polygon	Gorontalo Regional Office for Forest Area Consolidation and Environmental Management
Land Cover	Polygon	Gorontalo Regency Department of Public Works and Housing
Road type	Polyline	Geospatial Information Agency
Regional Administration	Polygon	
Grid	Polygon	
Food Supply	Tabular	Gorontalo Regency Central Statistics Agency, and Gorontalo Regency Department of Agriculture
Population	Tabular	Gorontalo Regency Central Statistics Agency

The research stages include three main processes, namely a) calculating food energy needs; b) calculating food energy availability; and c) determining the status of the Environmental Carrying Capacity of food suppliers. The first stage is calculated based on population distribution and Energy Adequacy Rate per capita/year. The spatial distribution of the population is based on road types and land cover classes. The second stage is calculated with the value of agricultural production and distributed based on the Environmental Service

Performance Index (ESPI) of food providers. The third stage is calculated by comparing the values of both which can be negative (-) for deficit, 0 for balanced and positive (+) for surplus.

In calculating the Environmental Carrying Capacity status of food suppliers, the approach used is grid-based (pixels: 0.1 km x 0.1 km). This approach was chosen because it is more representative from the perspective of regional planning which is directed at the potential supply-demand of the ecosystem in a closed manner. In this case, the grid is used to model the distribution of food energy availability and needs for a certain area unit. The 0.1 km x 0.1 km resolution grid was chosen because it can acquire more detailed data and does not experience significant distortion as in larger grid resolutions. The accumulation of calculations on each grid represents the Environmental Carrying Capacity status of food suppliers through a comparison of the level of need with the availability of food energy in the research area.

Calculation of Food Energy Requirements

Food energy needs are calculated by considering population distribution. Given that population distribution is greatly influenced by land class and road type, the calculation of population distribution is assumed to follow the weight of each class of both. In determining the amount of contribution from a type of road and/or land cover as a factor in mapping population density in the grid system, used is as follows (Nengsih, 2015).

$$Pij = \frac{Bij}{tBij}\ x\ tP \quad (1)$$

Description:
Pij : The population of the i-th grid of sub-district/city j (number of people)
Bij : Weight of the road/land class of the i-th grid sub-district/city j
tBij : Total weight of the sub-district/city area grid j
tP : Total population of sub-district/cities j (number of people)

Food energy needs are calculated based on the need for energy adequacy per capita/day in a time span of one year. The value of the energy adequacy recommended by the Ministry of Health of the Republic of Indonesia is 2100 kilo calories per capita/day (Permenkes RI No. 28/2019). To calculate the needs of the energy needs of each grid, the equation used is as follows (Norvyani & Taradini, 2016).

$$BPij = Pij\ x\ AKE\ x\ 365 \quad (2)$$

Description:
BPij : The energy requirement for the Grid in sub district/City J for a year (kcal)
Pij : The total population of the i-th Grid in sub-district/City J (number of people)
AKE : Energy needs per capita (2100 (kcal/days))

Calculation of Food Energy Availability

The availability of food energy is distributed following the value of the environmental service performance index. The environmental service performance index map was overlay with a grid of 0.1 km x 0.1 km so that one grid can have more than one polygon of the environmental service performance index. So that the environmental service performance index value is proportional to the grid, a significance calculation of the Polygon ESPI to the grid area is carried out with the following formulation (Norvyani & Taradini, 2016).

$$ESPI = \frac{pL}{gL} x\ pIKJLH \quad (3)$$

Description:
'ESPI : Proportion of Environmental Services Performance Index Against Grid
pL : Polygon area (m^2)
gL : Grid area (m^2)
pESPI : Environmental Services Performance Index Polygon

The entire 'ESPI on the same grid is added up to get ESPI Grid (gESPI). The same step is applied to all grids of the research area unit, one by one. Furthermore, all gESPI is added to get tESPI, which is mathematically written as follows.

$$tESPI = \sum_{i=1}^{j} gESPI \quad (4)$$

Description:
tESPI : Total ESPI in the J area unit used
∑gESPI : Addition of ESPI All sub-district/City Grid j

The sum of the entire grid (tESPI) will be used as an association of gESPI so that the proportion of the availability of food energy is obtained for each grid. Food production that has been converted into the form of energy is then distributed in each grid. Food availability is distributed based on gESPI values; The higher the status of gESPI to tESPI in the research area unit, the availability of food energy in the grid is assumed to be greater. To get the distribution of the availability of food energy for each grid, the following formula is used (KLHK, 2019).

$$TPij = \frac{gESPI}{tESPI} x\ TPw \quad (5)$$

Description:
TPij : The proportion of the availability of food energy for each grid (kcal)
ESPIg : Environmental service performance index for each grid
tESPI : Total Environmental Services Performance Index Grid
TPw : Availability of Food Energy Conversion of Regional Units (kcal)

Determination of the Carrying Capacity of the Environment of Food Suppliers

Determination of the environmental carrying capacity of food suppliers is to calculate the supply difference between the availability of food energy and food energy needs at the same grid. The formulation used in this calculation is.

$$Sij = TPij - BPij \quad (6)$$

Description:
Sij : Difference in food energy of the i-th grid in sub-district/city j (kcal)
TPij : Availability in food of the i-th grid in sub-district/city j for a year (kcal)
BPij : Need for the number of energy needs of the i-th grid in sub-district/city for a year (kcal)

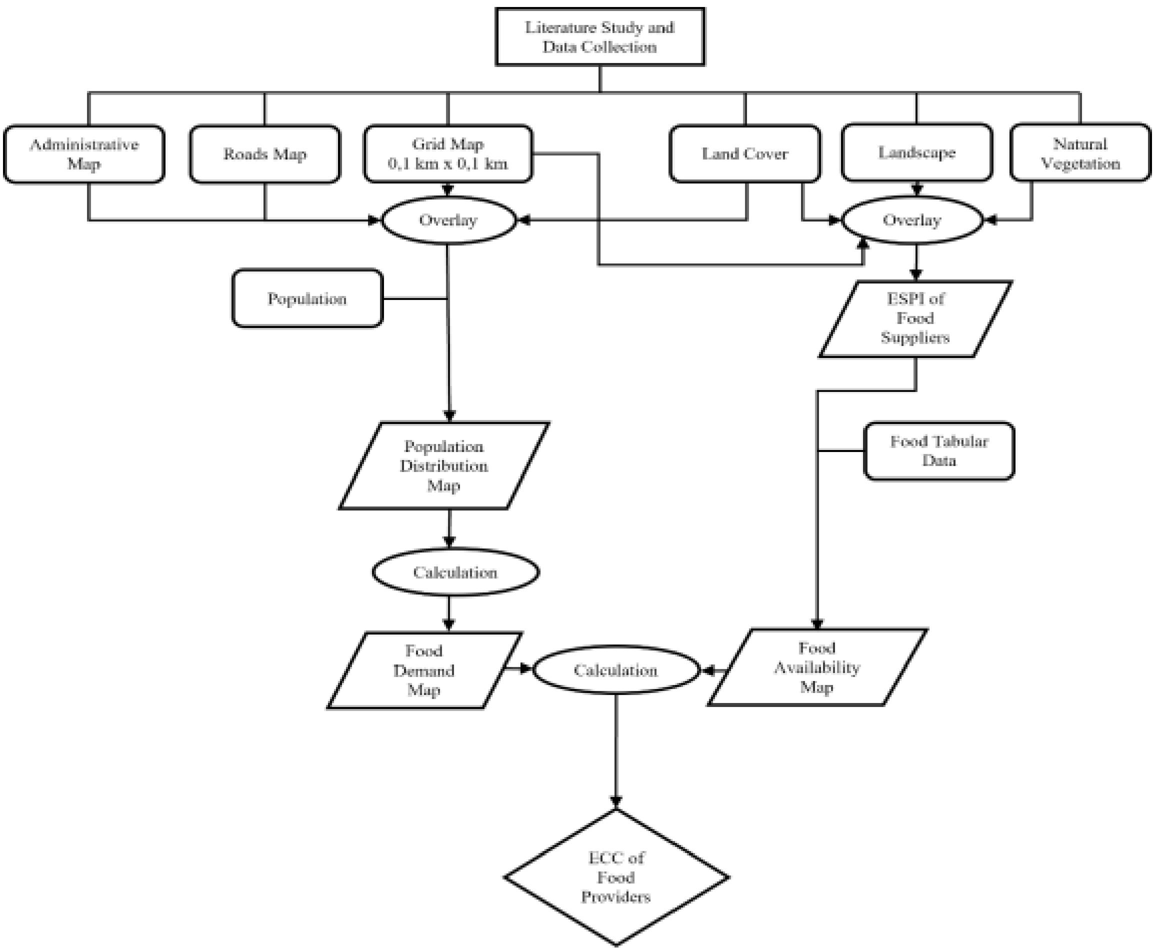

Figure 1. Research flow diagram

Result and Discussion

The discourse on the expansion of Talaga Jaya, Telaga, Telaga Biru and Tilango Sub-districts into second-level regions has emerged to the Gorontalo public since 2019 and Talaga City was only officially announced on January 23, 2020 in commemoration of the 78th Gorontalo Patriotic Day which brought together a number of community leaders and local governments (Pranala.co.id, 2020). Although this step was hampered (moratorium) due to the Covid-19 pandemic that soon hit, this aspiration is certain to remain alive with various promotional and socialization efforts through electronic media, print media and social media. The declaration of the expansion of the four sub-districts began to see a bright spot after receiving approval from the Governor of Gorontalo through the Decree of the Governor of Gorontalo Number 416/1/XI/2021 concerning the Approval of the Establishment of a New Autonomous Region of Gorontalo Province. From an administrative perspective, these Talaga City have also met the requirements to become a new expansion area based on Law of the Republic of Indonesia Number 23 of 2014 concerning Regional Government and Government Regulation Number 78 of 2007 concerning Procedures for the Formation, Elimination and Merger of Regions.

The area of the Talaga City above is 180.54 km^2, stretching from the northeast of Lake Limboto to the north in the Dulamayo Mountains. The economy of this region is quite dependent on the agricultural sector, but seeing the recent trend of social, economic and infrastructure development implies a movement towards urban characteristics, so that the initiative to expand the four sub-districts is considered relevant as an effort to prepare better regional governance/ management. Its strategic location as a satellite area (urban fringe) and passed by the Trans Sulawesi Road and GORR makes social and economic activities in this area quite lively. This encourages more efforts to adjust development in various sectors which in turn have an impact on the social and economic transformation in this area so that it develops into a trade and service area.

Food Energy Needs

The carrying capacity of environmental services is the maximum limit of the environment's capacity to accommodate population activities sustainably (Mirajiani, 2021; Sutrisno et al., 2023). Population is one of the important aspects that needs to be included in measuring the carrying capacity of food suppliers in a regional unit. This is because the benefits and environmental services supplied naturally are basically intended for the welfare and fulfillment of basic rights of the population (Costanza, 2020). The size of the population pressure on the environment affects the natural ability of the environment to supply and meet the population's food needs. In other words, an increase in the number of residents drives an increase in the consumption sector, thereby suppressing the capacity of environmental productivity (Aulia et al., 2021). This poses a major challenge for the world on how to meet the food energy needs of the population which continues to rise amidst the decline in agricultural land for construction and other activities (Sudipa, 2021).

Food energy needs are measured based on the distribution of population density in each grid. The determination of population density of a grid is the result of modeling according to the comparison of road weight and land cover of each grid to the total weight of the entire grid. The value generated in each grid is used as a factor in distributing the total population of SI input for each grid.

Most of the population in the research area is concentrated in the southern region as the center of settlements and social activities. The southern region has a gentle to flat topography so that the limitations and obstacles to development are relatively small. This makes development in this region more progressive and land conversion occurs very dynamically. In contrast, the northern region is a mountainous area with steep to very steep topography. Compared to the southern region, there are fewer villages in the northern region, but it has a large administrative area with a low population density. The distribution of the population has a linear pattern following the road network and some are spread out centrally at certain points. The number of residents with modeling results is presented in Table 2 below.

Table 2. Comparison of Input Population with Modeling Results

Sub-district	Population in 2022			%	Demand (kcal)
	SI Input	Model Result	Difference		
Talaga Jaya	13039	13034	-5	0.04	9990561000
Telaga	23648	23790	+142	0.6	18235035000
Telaga Biru	30568	30650	+82	0.27	23493225000
Tilango	17035	17026	-9	0.05	13050429000
Total Talaga City	84290	84500	+210	0.25	64769250000

Source: Data analysis result, Statistics Indonesia (SI) of Gorontalo Regency (2023); Department of Agriculture, Gorontalo Regency (2022)

Statistics Indonesia (SI) recorded that the population in the research area in 2022 was 84,290 people, while the modeling results showed a figure of 84,500 people with a difference of 210 people (0.25%) and an average of each sub-district below 1% or not significant. This means that the population distribution model into this grid system can be accepted for use in the next stage, including calculating the energy needs of each grid.

The food energy needs of each grid are the food energy needs of a number of residents in a grid over a period of one year. Both the need and availability of food energy are calculated in kilocalories (kcal) due to the variety of agricultural commodities used. Firmansyah et al. (2023) in their research on the same topic used kilograms (kg) with rice as the only commodity to measure the capacity of food supplier's ECC in the Gerbangkertosusila metropolitan area, East Java.

As is known, the Indonesian Minister of Health Regulation No. 28/2019 has set the optimum line for fulfilling food energy per capita at 2100 kcal/day. This means that at least a human being needs a food energy supply for his body of 766,500 kcal/year. If this figure is multiplied by the grid population model in the research area in 2022, then food energy of 647,692,50000 kcal is needed to meet the food energy needs of the entire population in the research area in that year. In this case, Telaga Biru Sub-district is recorded as having the highest level of food energy needs of 23.4 billion kcal, followed by Telaga Sub-district, Tilango Sub-district and Talaga Jaya Sub-district respectively of 18.3 billion kcal, 13 billion kcal and 9.9 billion kcal. The distribution of food energy needs in the research area can be seen in Figure 2.

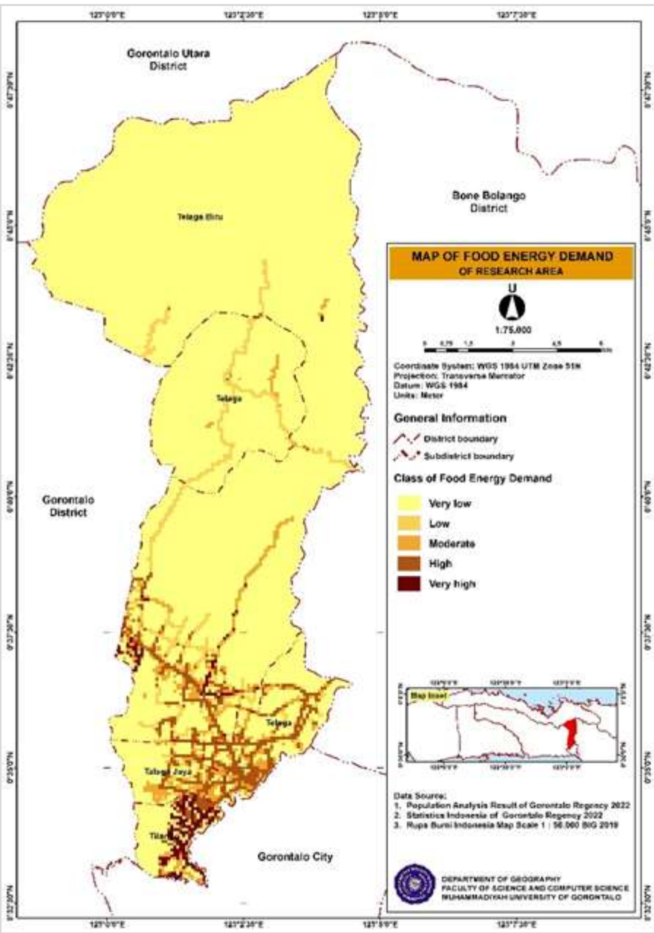

Figure 2. Map of food energy demand in the research area (Data analysis result)

Food Energy Availability

Food energy supply services are one of the various types of environmental services that indicate the carrying capacity of an area (Shi et al., 2020). Conceptually, the carrying capacity of food suppliers is directly proportional to food environmental services, which are indicatively measured spatially based on landscape characteristics, natural vegetation types and land cover (Nursalam et al., 2024; Rizkon et al., 2024). In this case, more dynamic land cover is a factor of economic and social capital correction because it is greatly influenced by human activities (Wang et al., 2021). Therefore, experts give a higher score to the land cover parameter than the other two parameters in seeing its significance to environmental services.

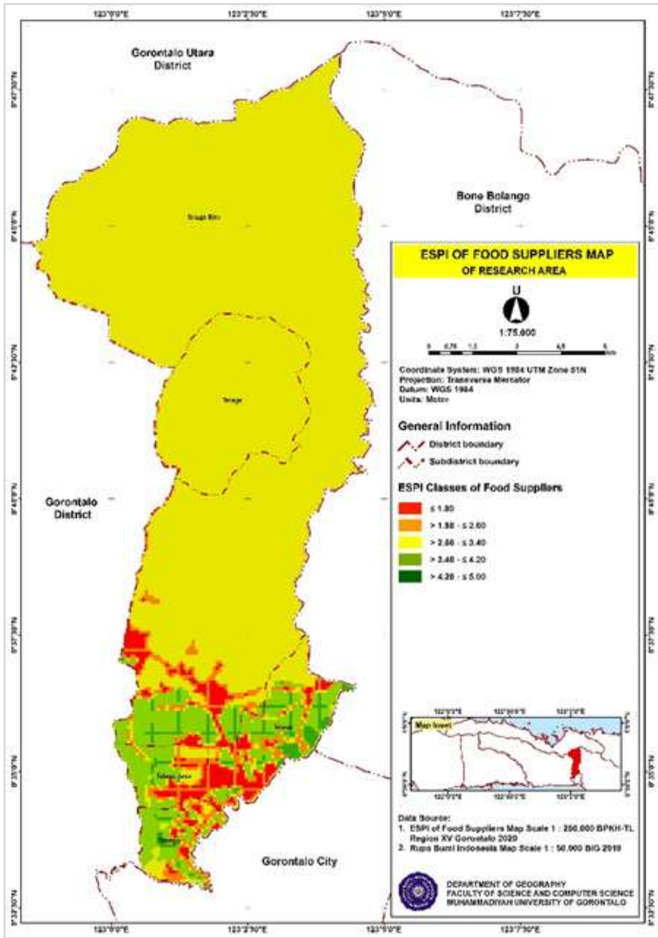

Figure 3. Distribution of ESPI classes of food suppliers in the research area as a factor in the distribution of food energy availability (Source: BPKH-TL Region XV Gorontalo)

The calculation of food energy availability in the research area is measured using the grid method. This method stipulates that the supply of food energy in a grid is allocated to meet the demand for food energy in the grid itself. The availability of food energy is distributed based on the ESPI value of the food supplier. In general, ESPI is understood as an indicative index that shows the potential of environmental services in providing environmental benefits naturally by ignoring external factors such as natural disasters, climate change, social conflicts and so on (Aulia et al., 2021; Baco S et al., 2020; Firmansyah et al., 2020; Rizkon et al., 2024). The ESPI value is obtained by accumulating the ecosystem benefits supplyd by the landscape and natural vegetation types and land cover as a correction factor for economic activities so that information on the value of an environment can be derived (Holik et al., 2022). Norvyani et al. (2016) and Sangadji et al. (2023) in their research used ESPI as a factor in distributing food energy with two parameters, namely landscape and land cover which refer to the area of polygon slices as their weighting values. The distribution of the ESPI of food suppliers in the research area can be seen in Figure 3.

Visually, the characteristics of the food supplier's ESPI divide the research area into two parts, with a homogeneous northern region and a heterogeneous southern region. Most of the food supplier's ESPI in the research area are in the "moderate" category (index value 2.61 - 3.40) and are mainly spread in the northern region. This is due to the largest multiplier factor, namely the land cover parameters in the northern region are dominated by dry land agriculture, forests and shrubs which contribute moderately to the potential for food supply services. Meanwhile, land cover in the southern region is more complex with settlements, wetland and dry land agriculture, open land, swamps, water bodies and others. The potential for providing food ecosystem services in this region is the highest, but at the same time it also records the lowest food supplier's ESPI in some areas.

Table 3. Conversion of Food Commodity Groups into Food Energy (Kcal)

Commodity Group	Production (kg)	Total Energy (kcal)
Horticulture	2674400	3324173000
Plantation	1445360	4389826300
Livestock	1154954,98	2657208709
Agriculture	29735315,8	41074403183
Total	35010030,75	51445611192

Source: Data analysis result, Statistics Indonesia (SI) of Gorontalo Regency (2023); Department of Agriculture, Gorontalo Regency (2022)

In general, the main source of food energy in the research area comes from rice commodities and other commodities cultivated on dry agricultural land. Rice commodities are produced from irrigated rice fields in the southern area of the research area Talaga City, precisely in Telaga Sub-district, Telaga Biru Sub-district and Talaga Jaya Sub-district. Meanwhile, dry land farming is mostly found in the northern area of the research area, especially in Telaga Biru Sub-district. The value and production of food energy availability are limited to commodities that have been superior commodities in the research area, have high energy conversion (kcal), the most basic basic needs circulating in the market and of course are consistently produced in the research area. Table 3 contains a list of superior commodity groups in the research area along with their energy conversion in the form of kilocalories (kcal).

The availability of food energy per grid is a modeling of energy (kcal) supplyd by a grid based on the ESPI value of each grid as a factor in the distribution of total food energy in the research area. The total food energy from the conversion of food materials is used as input to be distributed to each grid that intersects with agricultural land cover. The amount of food energy distribution (kcal) in each grid depends on the ESPI value of each grid.

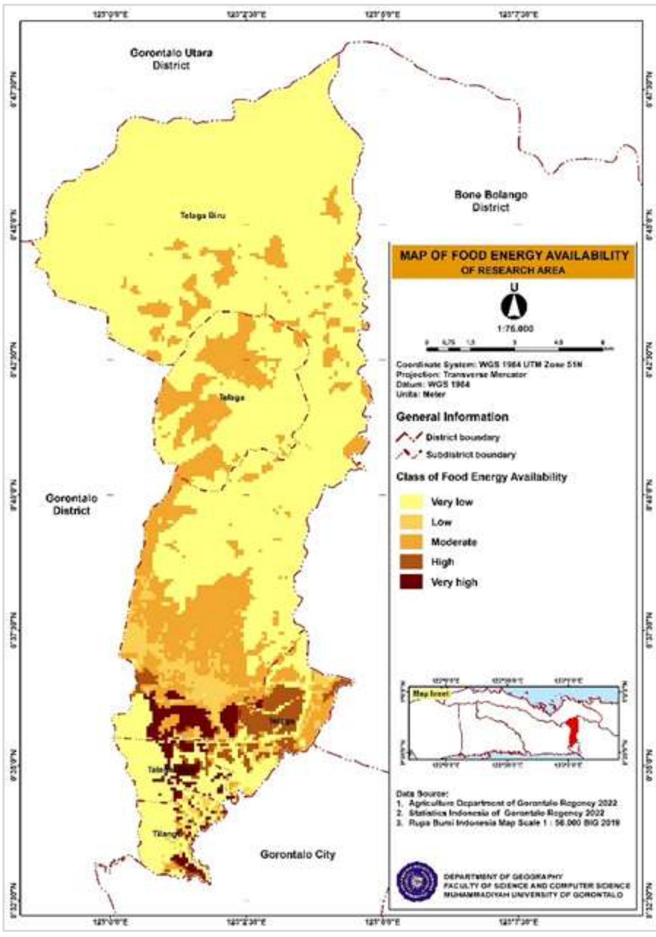

Figure 4. Map of food energy availability in the research area

The highest distribution of food energy availability per grid is in the southern area of the research area which is a downstream area and has flat topography. This area is the center of economic, social, residential and agrarian activities. The largest food energy in this area is produced from wet land agricultural commodities, in this case rice cultivated on irrigated rice fields.

Meanwhile, the northern area which is the upstream and/or middle area is dominated by dry land agriculture which also plays an important role as the backbone of food energy suppliers for the research area. The Figure 3 presents a map of the distribution of food energy availability in the research area.

Determination of the ECC Status of Food Suppliers

Evaluation of the Environmental Carrying Capacity of food supply in this region needs to be carried out because every development has the potential to encourage agglomeration (spatial concentration) and increase the intensity of human activity (Liu et al., 2018; Xu et al., 2020). Massive agglomeration without careful planning will lead to inefficient forms of food resource utilization. On the other hand, food resource productivity tends to stagnate so that the explosion of space utilization will increase pressure on food resources (Ruslan, 2021). Information on the Environmental Carrying Capacity of food supply can be the basis for formulating development planning policies and programs so that development in this region can be effective, efficient, harmonious, balanced and sustainable, helping to identify and allocate resources to places that need them most.

Determination of the environmental carrying capacity status of food suppliers in the research area unit is carried out by looking at the comparison between the need and the availability of food energy on the same grid. Any grid with food energy needs exceeding the availability threshold will be recorded as a deficit, requiring food energy from outside its environment. Conversely, any grid with food energy availability exceeding needs will have surplus status, while grids with the same food energy needs and availability will be read as balanced. Table 4 below contains a comparison between food energy needs and availability in Talaga City.

Table 4. Comparison of Food Energy Demand and Availability in Talaga City

Sub-district	Population	Demand (kkal)	Supply (kkal)	Difference (kkal)	S. Cap.	Status
Talaga Jaya	13034	9990561000	5480247853	-4510313147	-5884	Deficit
Telaga	23790	18235035000	15578413963	-2656621037	-3466	Deficit
Telaga Biru	30650	23493225000	27119836943	3626611943	4731	Surplus
Tilango	17026	13050429000	3267112434	-9783316566	-12764	Deficit
Total Talaga City	84500	64769250000	51445611192	-13323638808	-17382	Deficit

Source: Data analysis result

Descriptively, three sub-districts in the research area are unable to meet the food energy demand of their population independently. In this case, Tilango Sub-district is the most serious area, with a level of demand far exceeding what can be offered. Meanwhile, Telaga Biru Sub-district with the highest food production in the area is the only sub-district that is able to meet the needs of its population independently. The spatial distribution of the ECC status of food suppliers in the research area in 2022 can be seen in Table 5 below.

Table 5. Distribution of Food Supplier's ECC Status in the Research Area

Sub-district	ECC Status (km²)			Total
	Deficit	Balanced	Surplus	
Talaga Jaya	2.67	2.44	1.73	6.84
Telaga	6.00	15.68	14.05	35.73
Telaga Biru	8.95	100.41	22.52	131.88
Tilango	2.41	2.33	1.15	5.89
Total Talaga City	20.03	120.86	39.45	180.34
%	11.11	67.02	21.88	100

Source: Data analysis result

Spatially, the research area recorded a wider distribution of food energy surplus than deficit, with a distribution covering 21.88% compared to 11.11%. However, the escalation of this surplus value is not as deep as that of the area in deficit conditions, so that even if all the remaining food energy owned by the surplus grid is distributed or allocated to all deficit grids, it will not be enough to cover the existing shortage. This result is different from the findings of Norvyani et al. (2016) in mapping the food carrying capacity threshold in West Bandung Regency, West Java, where 59.54% of the area is in surplus condition and is able to distribute food energy to some deficit areas. On the other hand, the status of the ECC of food supplier in these four sub-districts is similar to the condition of the ECC of food supplier in Palu City, Central Sulawesi, with 46.09% of its area in deficit status and insufficient if supplied with food energy from surplus areas (Sangadji et al., 2023), as well as the results of the research by Firmansyah et al. (2023) who found that 89% of the Gerbangkertosusila metropolitan area, East Java is in a food energy deficit status. This is the main point that distinguishes between non-spatial analysis and spatial-based analysis. Non-spatial analysis will calculate all comparisons between the two parameters studied and present them descriptively according to certain administrative boundaries (Mardiana et al., 2023; Mirajiani, 2021), while spatial analysis has more value in the ability to model the data so that it can be used, among other things, in identifying the condition of regional units for the purpose of allocating food resources to the places that need it most. The ECC status map of food suppliers in the research area can be seen in Figure 5.

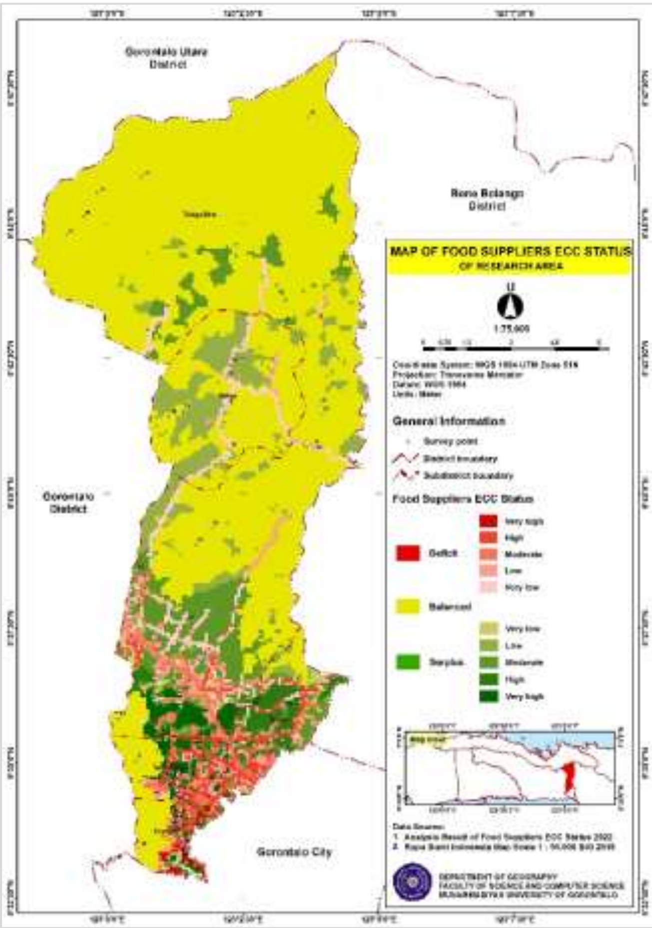

Figure 5. Map of Food Supplier's ECC Status in the Research Area in 2022

The spatial distribution of deficit status is centered in the southern region because it is the center of spatial concentration, on the other hand the southern region is also a rice field area so that it becomes the basis of food production in this region. This area is designated as a cultivation area, especially agriculture and settlements. However, considering that this area is also an area prone to natural disasters, especially floods, while the food supply in the research area is not comparable to the level of food demand, it poses its own challenges for this region in terms of food security, especially when natural disasters occur.

The availability of food with the largest energy conversion value is distributed in the southern region of the research area, which is none other than the region with the largest food energy needs. This region has reached its peak production and population growth in this area can no longer be supported. Meanwhile, the northern region is an area with high development limitations, making it difficult to develop into a new agricultural area and/or as a settlement center. In this region, the potential for food supply services is moderate, but has not been able to supply sufficient food energy because the agricultural commodities cultivated in this region have a relatively small energy conversion per gram.

Based on the results of the analysis, the research area requires more food-producing grids just to balance the needs of one grid. In this case, agricultural land degradation and conversion to non-agricultural uses can further worsen the condition of food support capacity in the research area. By comparing the needs with the availability of existing food energy, the research area is in a food energy deficit status. Without the flow of food energy from outside the area, the capacity of the ECC of food supplier can only accommodate a maximum population of 67,181 people, quite far from the existing population model of 84,500 people. In other words, the research area does not achieve food self-sufficiency so that it requires flows from outside the area in order to meet domestic food energy needs. This figure also indicates the level of need for agricultural land in the research area which is greater than what can be currently supplied. The existence of internal gaps in the ECC of food supplier means that the population in the research area cannot grow because the food support capacity has reached its limit. The need for food energy in a region is in line with the population growth rate in the region itself. The population growth rate can be influenced by many factors, including birth rates, death rates, transmigration and other factors such as economic growth, life expectancy, policy factors and so on. Population growth in the research area in the last 10 years is relatively low. However, the population growth trend is positive, which means it continues to increase in the following years. Of course, this increase in population has an impact on the level of domestic food demand which also increases. On the other hand, the environment's ability to produce and offer food is limited. The following Figure 6 contains a projection of the population in 2035 based on the population growth trend in the last 10 years in the research area and its relationship to the level of demand for food energy.

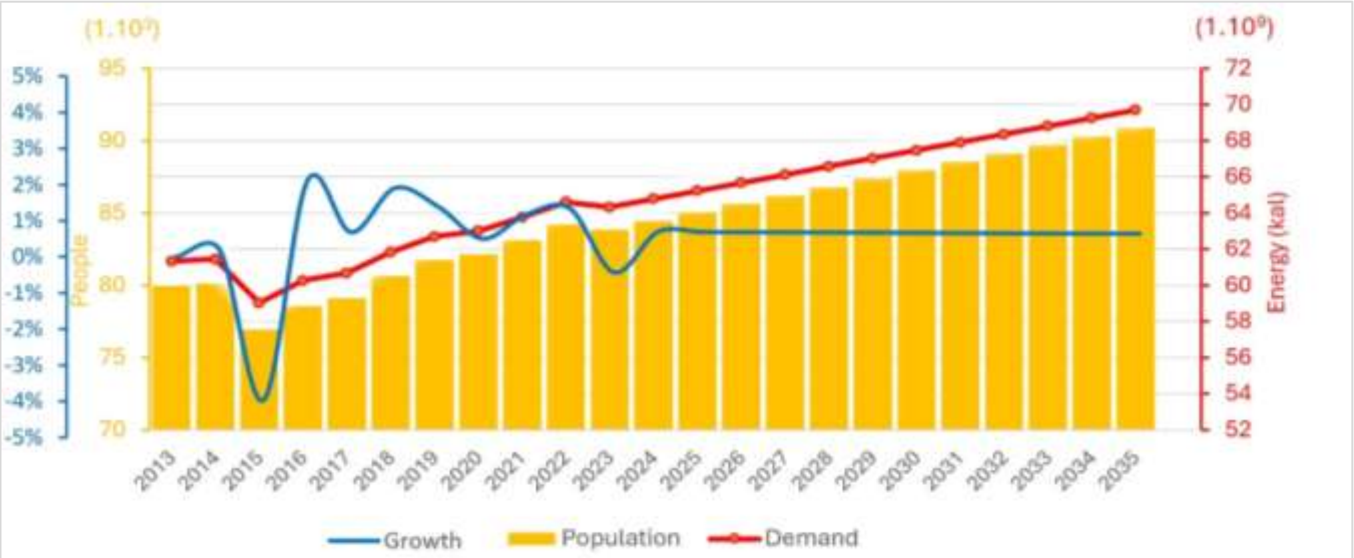

Figure 6. Projection of population and food energy demand levels in the research area until 2035 (Source: Data analysis result)

The average annual population growth in the research area in the last ten years has almost never exceeded 2%, even recording negative in a number of years. It is estimated that in the coming years the research area will experience monotonous population growth. Based on the projection results using linear trend analysis, it is estimated that the population in the research area in 2035 will reach 90,937 people, an increase of 9.32% from 2022 which was only 83,178 people. This figure also increases the demand for domestic food energy by ±69 billion kcal in the same year. Tilango Sub-district is predicted to experience the largest population increase among the other three sub-districts with a percentage increase of 21.04%, followed by Talaga Jaya, Telaga Biru and Telaga Sub-districts by 13.88%, 5.25% and 3.77% respectively. The following Table presents the results of population projections and the level of demand for food energy for each sub-district in 2035.

Table 6. Projection of Population and Food Energy Demand in 2035

Sub-district	Population	Demand (kkal)	Status
Talaga Jaya	14600	11190616395	Deficit
Telaga	24309	18632636946	Deficit
Telaga Biru	31847	24410702505	Surplus
Tilango	20182	15469748280	Deficit
Total Talaga City	90938	69703704126	Deficit

Source: Data analysis result

The research area projected as a New Autonomous Region in the future Talaga City, is faced with increasingly real ecological challenges. The population and the need for food energy are increasing over time, while productive agricultural land tends to decline due to the impact of urbanization and city development, requiring the adoption of appropriate, fast and efficient alternative solutions. Considering that the research area has been projected as an urban area so that the extensification of agricultural areas is considered less relevant to urban functions, therefore stakeholders can take policies to increase production and productivity of agricultural commodities through agricultural intensification and diversification aimed at local consumption (Kremen, 2020; Nicholls et al., 2020). Efforts are made as much as possible to maintain existing ecological conditions and prevent greater deficits in the future (Pourebrahim et al., 2023).

Conclusion

Spatially, the distribution of ECC of food suppliers in the research area is in deficit status of 20.03 km² (11.11%), balanced of 120.86 km² (67.02%) and surplus of 39.45 km² (21.88%). Deficit areas are spread across land cover types that have population value, including agricultural and forest land cover. Surplus areas are spread across agricultural land cover types, whether or not they intersect with the population. The balanced area is an area that does not offer and require food energy. Descriptively, the research area as a whole experiences a food energy deficit. The need for food energy in 2022 reached 64.7 billion kcal, while existing food production was only able to supply food energy of 51.4 billion kcal. Thus, agricultural production in the research area was only able to support 79.4% of its population. With the condition of the research area which is in a food energy deficit status in the existing year, the escalation of inequality in the future has the potential to be even sharper if it is not accompanied by an increase in commensurate food production results. Therefore, in order to maintain the demand for food energy in the future under control by existing supply, it is important to increase agricultural production through innovation and adoption of plant varieties that are resistant to climate change, strengthening agricultural infrastructure such as irrigation for efficient water use, crop diversification, reducing food waste and wise population planning. In addition, the government can take a policy of importing food from outside the research area to meet the demand for food energy in the research area Talaga City.

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Conceptualization, T.D., S.M.D., and A.S.R.S.; methodology, T.D., and S.M.D.; software, data analyzer and visualization S.M.D., and A.S.R.S.; writing—review and editing, T.D., S.M.D., A.S.R.S., I., and K.M.M.; supervision, A.S.R.S., and I.M.

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The authors declare no conflict of interest.

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