Spatial and temporal dynamics of agricultural land carrying capacity (LCC): a case study of Jombang District, Indonesia

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Abstract. Agriculture becomes one of the essential sectors in supporting food security. Nevertheless, in many cases around the world, vast urbanization often leads to an imbalance of resource consumption and its carrying capacity including the land. This paper explores the status of agricultural land carrying capacity from the perspective of spatial and temporal dynamics in Jombang District, Indonesia. Jombang is one of the regions in East Java Province that significantly contributes to crop production. More than 50% of the land use in Jombang is agricultural land. Yet, the spatial dynamics affected by several factors such as distance to the nearest city, industrialization, road infrastructure, and built-up density, as well as government policy on spatial planning might have some impacts on the agricultural land in Jombang during the last several years. To assess and extrapolate the existing and future agricultural land carrying capacity, we conducted three analyses comprising the following: (1) agricultural land cover change; (2) agricultural ecological footprint and its biocapacity; and eventually (3) the agricultural land carrying capacity. All the analyses are based on the temporal dynamics considering the past, the existing, and the future. The findings suggest that agricultural policy, spatial plan, and programs should be maintained continually towards surplus status of LCC.

1 Introduction

Agriculture becomes one of the essential sectors in supporting food security. Nevertheless, fast urbanization often leads to an imbalance of resource consumption and its carrying capacity including the land [1,2]. In order to predict the food security in the future especially at the local context, Land Carrying Capacity (LCC) can be conducted. The concept of carrying capacity is defined as a density-dependent concept in referencing the maximum amount or size that can sustain indefinitely in its environment [3]. As this concept can be extended into the ecological dimension, this paper adapts the definition defined by the Indonesian Minister of Environment and Forestry Regulation No, 52/2016 regarding norms, standards, procedure, and criteria of ecoregion development control stating that environmental carrying capacity is the ability of the environment to support the life of living

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things [4]. In this study, land is one part of the environmental carrying capacity that can be interpreted as the land capacity to accommodate the agricultural activity.

Similar studies have simulated the status of LCC, for instance for all land use in Bali [5] and in Gerbangkertosusila† Region in the East Java Province [6]. This study adopts the methodology used in those two studies that calculate the status of LCC using the calculation approach of comparing between biocapacity and ecological footprint. That approach is closely depended on the land availability. Therefore, agricultural land availability is crucial to the LCC. On the other side, the changes in land use/land cover (LULC) especially for vegetation land such as forest and agricultural land is largely encouraged by rapid and vast population growth [7]. This agricultural land conversion gives an impact to the agricultural land availability, agricultural productivity, and eventually food security.

Jombang District is one of the regencies in the East Java Province that has potential in the agricultural sector. The agricultural sector is one of the main pillars and drivers of the Jombang's economy [8,9]. Based on its spatial plan in the year 2021-2041, Jombang District aims to become the center of agribusiness and cultural development supported by the potential of agriculture, industry, trade, tourism, and traditional arts for equitable sustainable development [10]. The emphasis on the agribusiness center with the development of agricultural sector is supported by the strategies on allocating the agricultural land in its spatial plan, consisting of 38,149 Ha of Sustainable Food Agricultural Area (KP2B) spread in 20 out of 21 sub-districts, 10.417 Ha of plantation area, and 3,924 Ha of horticultural area. This number approximately reaches almost 50% (47.3% to be precise) of the total land in this District.

Agricultural sector becomes the leading sector in Jombang District. Nevertheless, the spatial dynamics including urbanization in the given temporal dimension could change agricultural land availability in the case study. This study explores the status of the agricultural LCC of Jombang District for the next 20 years, emphasizing on the factors related to the spatial and temporal dynamics.

2 Method

2.1 Selection of determinants for the agricultural land conversion

Some studies have identified LULC conversion especially the types that are related to vegetation land conversion. A study in 2023 [11] investigated the changes of grassland to cropland and vice versa using an indicator system as the driving factors. The study included the driving factors from both inside and outside the cropland-grassland system or from an integrated internal and external multifactor perspective. Intrinsic or internal drivers consisted of identity conditions (cultivated land area, cultivated land quality grade, grassland area, percentage of high-covered grassland) whereas external drivers comprised natural background (Change in average temperature, Change in average precipitation, Relief of terrain), geographical location (Distance of the geometric centre of cultivated/grassland from the nearest traffic road, Distance of the geometric centre of cultivated/grassland from the nearest settlement, Distance from the geometric centre of cultivated/grassland to the nearest water source), economic development (change in Gross Domestic Product or GDP, change in output value of secondary and tertiary industries, change in value added of agriculture, change in value added of livestock, change in total agricultural machinery power input,

† Gerbangkertosusila is a local name for the Surabaya metropolitan area or Greater Surabaya, in East Java, Indonesia. Gerbangkertosusilo is an abbreviation of the names of the cities and districts comprising of Gresik District-Bangkalan District-Mojokerto City-Mojokerto District-Surabaya City-Sidoarjo District-Lamongan District.

change in total social fixed asset investment), social progress (change in total population, change in urbanisation rate, change in total employed population in rural areas, change in total retail sales of social consumer goods), policy implementation (area of returning farmland to forest and grass, expenditure on ecological compensation, area of nature reserves, balancing cropland occupation and compensation policy).

To be specifically discuss the agricultural land conversion, a study in 2009 [12] found that agricultural land conversion was stimulated by internal factors such as farm size/farm slope, distance to nearest city, technology intensity, and productivity, as well as external factors among others were industrialization, road infrastructure, government policy, and urbanization. Another study conducted in 2021 [13] extracted major drivers of agricultural land use change which entailed of impact of urbanization (housing density, population density, percent urban population, and percent rural population), availability of agricultural labour (rural work force and urban work force), ageing of farm labour, cross sectoral mobility of labour, geophysical factors (terrain class, soil group, soil suitability class, slope class, relative humidity, elevation class, maximum temperature, and minimum temperature), accessibility (distance to major rail, distance to major road, distance to major river, distance to minor road) and climatic factors (total rain and number of raining days) [14]. Another study in 2022 [15] used 9 important factors divided into two broad categories of natural factors and human factors adapted from [16] and [17]. This included elevation, slope, temperature, and precipitation from the natural factors and population density, distance to highways, distance to railways, distance to the cities, and distance to rivers from the human factors.

We limit our study to include the factors of the agricultural land conversion that are only driven by spatial phenomena or dynamics such as the presence of urbanization, industrialization, regional infrastructure, and spatial planning and policy. Those determinants are derived into the following indicators:

1. urbanization: building density and centre of activities;
2. regional infrastructure: road infrastructure;
3. industrialization: industrial area;
4. government plan and policy: Sustainable Food Agricultural Land (LP2B), spatial plan for agricultural and industrial areas, road infrastructure, and centre of activities.

2.2 Data collection and data analysis method

This study utilized secondary data from Environmental Systems Research Institute (ESRI)[‡], the Government of East Java Province, and Statistic Agency of East Java Province. To simulate the agricultural LULC change from 2017-2043, we used the LULC time series map from 2017-2022 that were obtained from ESRI 10m Annual Land Cover. The maps were derived from ESA Sentinel-2 imagery at 10m resolution [18]. Each map is a composite of LULC predictions for 9 classes[§] throughout the year in order to generate a representative snapshot of each year. To be able to see the change pattern, we try to conduct 3 simulations of LULC change in the future with some determinants as mentioned previously, including

[‡] ESRI stands for Environmental Systems Research Institute, Inc., a company that develops geographic information system (GIS) software. Esri is a global leader in the GIS software market, and is known for its ArcGIS products.

[§] 9 classes of LULC: water areas, trees, flooded vegetation, crops, built up area, bare ground, snow/ice, clouds, and rangeland. In this study, we used crops area as the representative of agricultural area.

urbanization, regional infrastructure, industrialization, and government policy and plan regarding spatial plan and agriculture.

The Spatial Plan Year 2023-2043 of the East Java Province [19] was accommodated to as the determinants to forecast the agricultural LULC with the plan of agricultural and industrial areas, road infrastructure, and city/centre of activities included. Another determinant is building density with the basic data of built-up area that was acquired from Open Street Map [20]. Agricultural statistics from year 2017-2023 published by Statistic Agency of East Java Province [21] with the variable of land, production, and productivity were gathered as the basis input for calculating biocapacity and ecological footprint. We limit the scope of agriculture that refers only to paddy commodity which tend to have the biggest area among all crops and plantations in Jombang District.

Analyses were done in the unit of sub-district in Jombang District. To be able to forecast the LCC in Jombang District, several stages of analysis were performed with the details presented by the following Table 1.

Table 1. Method of analyses

Stage	Objective	Formula/ Analysis Technique	Description
Stage 1	To simulate the agricultural LULC change from 2017-2043	To be able to see the pattern change of agricultural LULC, we conducted 3 scenarios that differentiated determinants as follows. - *Scenario 1:* existing road infrastructure and building density - *Scenario 2:* existing road infrastructure, building density, industrial areas plan, road infrastructure plan, and centre of activities plan - *Scenario 3:* existing road infrastructure, building density, Sustainable Food Agricultural Land (LP2B), agricultural and industrial areas plan, road infrastructure plan, and centre of activities plan The scenarios were simulated using Plug-in in QGIS software called Modules for Land Use Change Simulations (MOLUSCE). This plug-in provides a set of algorithms for land use change simulations such as ANN, LR, WoE, MCE** that also uses kappa statistics as its validation [22]. This plug-in was developed by Asia Air Survey and NextGIS. We performed the simulation using ANN. ANN relies on the artificial intelligence to predict the change by recognizing and classifying land change and development patterns through learning process based on the interaction of land change factors on the past and its trends [23]. We converted all the determinants into raster version and used the Euclidean distance from each raster of each determinant to interact with the agricultural land distribution. The statistical pattern from those interactions were used by the ANN to predict the future model.	
Stage 2	To calculate agricultural biocapacity and ecological footprint from 2017-2043	BC = A*YF*EQF YF = YNL/YWL	BC = Biocapacity (gha) A = Agricultural LULC area (Ha) YF = Yield Factor EQF = Equivalence Factor YF = Agricultural yield factor (harvest factor) YNL* = Agricultural productivity of the calculated area (tons/Ha/year) YWL = Global agricultural productivity (tons/Ha/year) The equivalence factor values in this study is 2.52 that refers to the value of the EQF of agricultural land use in the Working Guidebook to the National Footprint and Biocapacity Accounts [24].
		EF = (P/YNL)* YF*EQF	EF = Ecological Footprint (gha) P = Agricultural production of the calculated area (tons) YN = Agricultural productivity of the calculated area (tons/Ha/year) YF = Yield Factor EQF = Equivalence Factor
Stage 3	To forecast the agricultural LCC from 2023-2043	LCC = BC/EF	LCC = Agricultural Land Carrying Capacity BC = Biocapacity (gha) EF = Ecological Footprint (gha) LCC score ranges from <1 to >1, <1 can be interpreted as an overshoot or deficit where the land is not able to support the agricultural activity, whereas > 1 is a surplus where the land is able to support the agricultural activity [5].

** Artificial Neural Network (ANN), Logistic Regression (LR), Weight of Evidence (WoE), and Multi-Criteria Evaluation (MCE)

4 Results

4.1 Agricultural Land Use Land Cover (LULC) Change

Agricultural land in Jombang District experienced an overall declining trend from the last 6 years from 57,125 Ha in 2017 to 56,675 Ha in 2022. This shows only 0.7-0.8% decrease with fluctuated trend during 2018-2022 as shown in Fig 1. This fluctuation can be generated by the accuracy provided by ESRI LULC. The previous statement was supported by a study in 2024 [25] that resulted a finding about the accuracy ranged in ± 70% when using the crops LC class gathered from ESRI LULC.

When simulating the 3 scenarios, it can be observed that scenario 1 leads to moderate scenario with almost constant change during the next 20 years forecasting if compared to the year 2022. In scenario 1, we included existing road network and building density, and this seems that the two variables did not significantly affect the agricultural land change for the next 20 years. The total length of the road network in Jombang District in 2022 is 597 km, consisting of artery road (7.4%), collector road (11%), and local road (81.5%). Dominantly, the road network found in Jombang District is categorized as local road that does not really drive the agricultural land conversion. Similar mechanism is also valid for the determinant of the built-up areas. In 2022, the built-up areas only take for about 21.35% of the total area and is also predicted to be in the similar proportion in 2043 for all scenarios.

Besides the road network and building density, other determinants comprising industrial areas plan, road infrastructure plan, and centre of activities plan were added in scenario 2. Those additional determinants could drive a slight change on the agricultural land with the decrease of only 0.1% in 2043 compared to 2022. This also shows that the plan of industrial areas, road infrastructure in the form of highway/toll, and centre of activities cannot really attract the agricultural land conversion. The presence of industrialization and urbanization in Jombang District both existing and in the future are not too prominent compared to the cities and other regencies in the East Java Province. From the spatial plan of East Java Province and Jombang District, it is known that the industrial areas are designated in Bandarkedungmulyo, Kabuh, Kudu, and Ploso sub-districts with the total area of 1,680.42 Ha or only 1.5%. The centres of activities are dominantly distributed around the centre of the region that are in Jombang, Ploso, and Mojoagung sub-districts. There also two promoted sub-districts in Sumobito and Bandarkedungmulyo sub-districts. Those five sub-districts take about 18.59% of the total area in Jombang District. However, it should be noted that not all areas of these five centers have undergone urbanization. From the comparison between Fig.1 and Fig.2, we still can detect that the agricultural land areas are still dominating the LULC in those 5 centres especially in Ploso, Mojoagung, Sumobito, and Bandarkedungmulyo sub-districts.

In contrast with scenario 1 and 2, scenario 3 is the optimist scenario for the agricultural land areas as it does not only accommodate the driving factors of the land agricultural land conversion, yet it also promotes the constraints of protecting and maintaining the agricultural land with applying the government policy and plan of Sustainable Food Agricultural Land (LP2B) and agricultural land area in spatial plan. If effectively implemented, those policy and plan become a powerful control to sustain the future of agricultural plan. The simulation in scenario 3 forecasts that there will be an increase of 3.72% of the agricultural land (from

56,675.84 Ha in 2022 to 58,782.81 Ha in 2043) if the government successfully executes that plan.

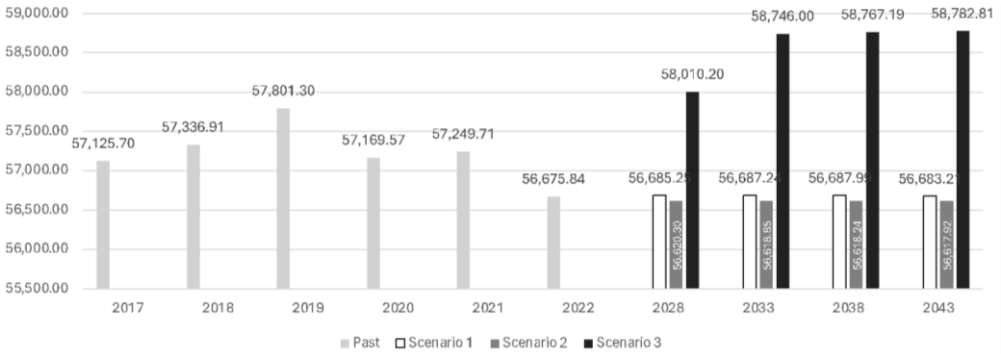

Fig 1. Agricultural land simulation from 2017-2043 in Ha unit with 3 scenarios.

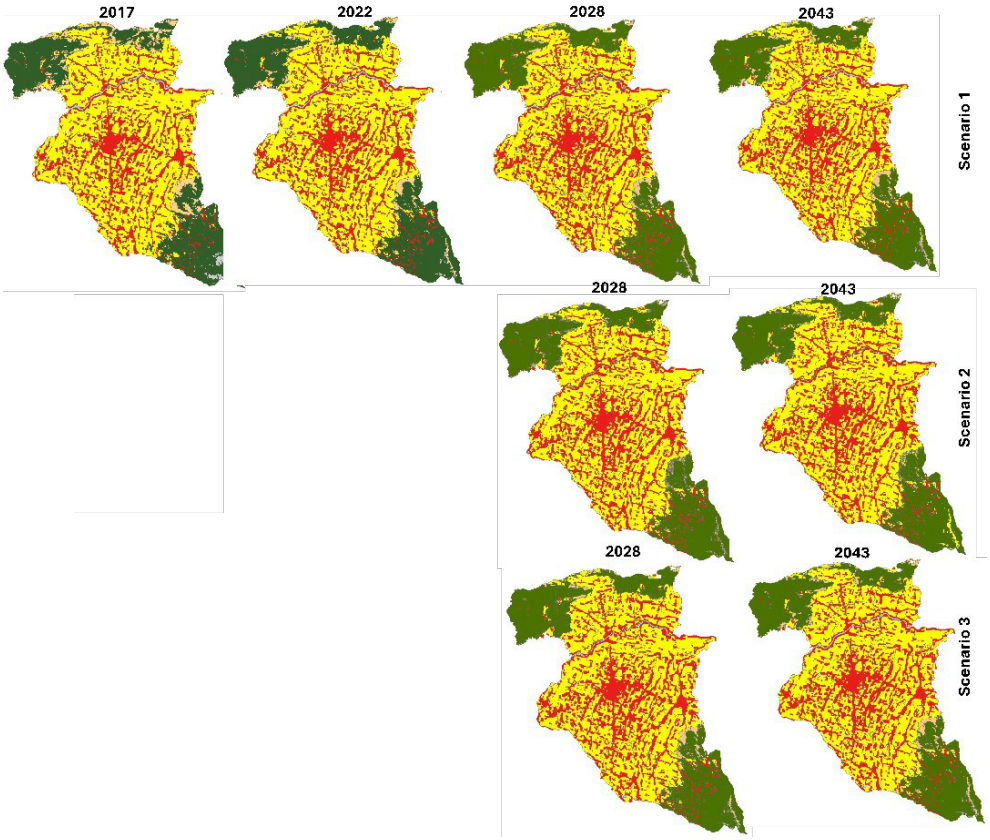

Fig 2. LULC simulation from 2017-2043 with 3 scenarios.

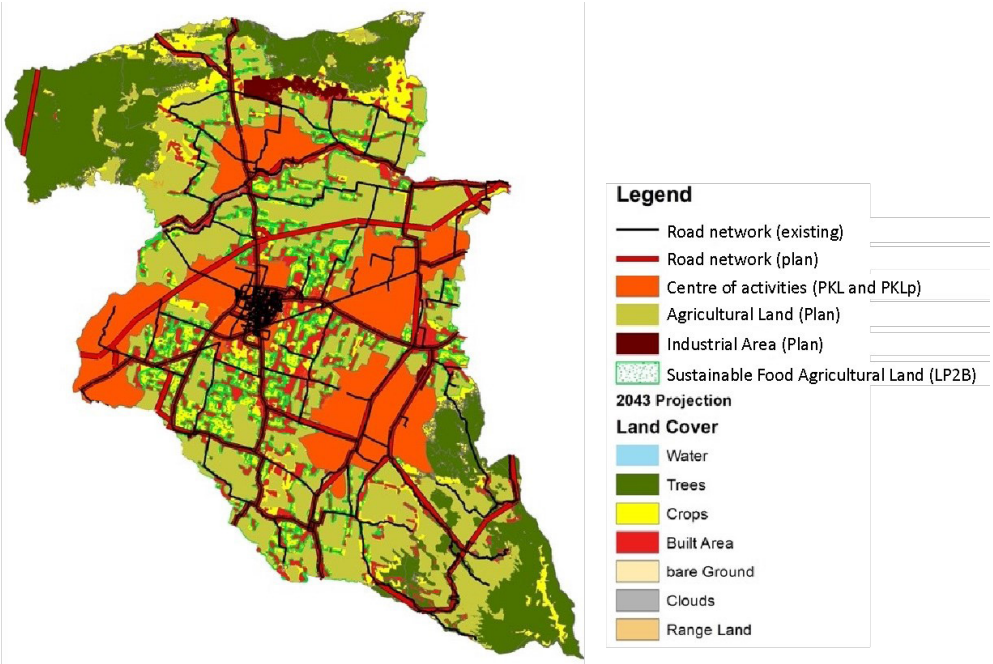

Fig 3. LULC projection in 2043 using scenario 3.

4.2 Biocapacity, Ecological Footprint, and LCC Calculation of the Agricultural Land

The details of the calculation of biocapacity (BC), ecological footprint (EF), and land carrying capacity (LCC) for each scenario are performed in Table 2, Table 3, and Table 4 by following the method and formula in Table 1. The same patterns are shown by the 3 scenarios with the EF in the past years of 2017-2022 are larger than the BC in the past years of 2017-2022. This resulted to deficit status of LCC during 2017-2022. Conversely, it is predicted that the status of LCC in the future up until 2043 for all scenarios are balanced or indicating to the increasing number of LCC (towards a surplus status). In 2028-2043, it is projected that the BC has, more or less, similar numbers with the EF.

A key factor affecting the increasing status of the LCC is the increased productivity caused by the increasing trend of agricultural production. The total paddy production in 2017 was 446.743 tons and it experienced 2.5% of increase to 448.109 tons in 2022. With not that much of the agricultural land change, this production increase is one of the key factors of the increasing production as well as productivity trend.

Table 2. Biocapacity, ecological footprint, and LCC calculation of the agricultural land for scenario 1

Scenario 1	2017	2018	2019	2020	2021	2022	2028	2033	2038	2043
A (Ha)	57,125.70	57,336.91	57,801.30	57,169.57	57,249.71	56,675.84	56,685.25	56,687.24	56,687.99	56,683.21
YNL (tons/Ha/year)	5.89	6.40	6.62	6.15	6.37	6.22	8.29	8.68	9.07	9.45
YWL (tons/Ha/year)	8.86	8.78	8.96	9.04	9.04	9.04	9.20	9.35	9.51	9.68
YF	0.67	0.73	0.74	0.68	0.70	0.69	0.90	0.93	0.95	0.98
EQF	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52
BC (gha)	**95,760.00**	**105,340.50**	**107,630.25**	**97,974.98**	**101,606.15**	**98,234.36**	**128,788.90**	**132,605.75**	**136,170.65**	**139,471.89**
P (tons)	446,743.00	480,258.00	422,051.89	462,090.48	475,767.18	448,109.84	476,209.68	496,672.17	517,134.67	537,597.16
YNL (tons/Ha/year)	5.89	6.40	6.62	6.15	6.37	6.22	8.29	8.68	9.07	9.45
YF	0.67	0.73	0.74	0.68	0.70	0.69	0.90	0.93	0.95	0.98
EQF	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52
EF (gha)	**127,070.77**	**137,879.71**	**118,720.25**	**128,766.25**	**132,577.41**	**124,870.41**	**130,450.54**	**133,862.45**	**137,032.53**	**139,952.98**
LCC	**0.75**	**0.76**	**0.91**	**0.76**	**0.77**	**0.79**	**0.99**	**0.99**	**0.99**	**1.00**
Status	**Deficit**	**Deficit**	**Deficit**	**Deficit**	**Deficit**	**Deficit**	**Balanced**	**Balanced**	**Balanced**	**Balanced**

Table 3. Biocapacity, ecological footprint, and LCC calculation of the agricultural land for scenario 2

Scenario 2	2017	2018	2019	2020	2021	2022	2028	2033	2038	2043
A (Ha)	57,125.70	57,336.91	57,801.30	57,169.57	57,249.71	56,675.84	56,620.30	56,618.85	56,618.24	56,617.92
YNL (tons/Ha/year)	5.89	6.40	6.62	6.15	6.37	6.22	8.45	8.83	9.22	9.61
YWL (tons/Ha/year)	8.86	8.78	8.96	9.04	9.04	9.04	9.20	9.35	9.51	9.68
YF	0.67	0.73	0.74	0.68	0.70	0.69	0.92	0.94	0.97	0.99
EQF	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52
BC (gha)	**95,760.00**	**105,340.50**	**107,630.25**	**97,974.98**	**101,606.15**	**98,234.36**	**130,991.90**	**134,784.69**	**138,322.71**	**141,596.83**
P (tons)	446,743.00	480,258.00	422,051.89	462,090.48	475,767.18	448,109.84	476,209.68	496,672.17	517,134.67	537,597.16
YNL (tons/Ha/year)	5.89	6.40	6.62	6.15	6.37	6.22	8.45	8.83	9.22	9.61
YF	0.67	0.73	0.74	0.68	0.70	0.69	0.92	0.94	0.97	0.99
EQF	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52
EF (gha)	**127,070.77**	**137,879.71**	**118,720.25**	**128,766.25**	**132,577.41**	**124,870.41**	**130,450.54**	**133,862.45**	**137,032.53**	**139,952.98**
LCC	**0.75**	**0.76**	**0.91**	**0.76**	**0.77**	**0.79**	**1.00**	**1.01**	**1.01**	**1.01**
Status	**Deficit**	**Deficit**	**Deficit**	**Deficit**	**Deficit**	**Deficit**	**Balanced**	**Balanced**	**Balanced**	**Balanced**

Table 4. Biocapacity, ecological footprint, and LCC calculation of the agricultural land for scenario 3

Scenario 3	2017	2018	2019	2020	2021	2022	2028	2033	2038	2043
A (Ha)	57,125.70	57,336.91	57,801.30	57,169.57	57,249.71	56,675.84	58,010.20	58,746.00	58,767.19	58,782.81
YNL (tons/Ha/year)	5.89	6.40	6.62	6.15	6.37	6.22	8.32	8.65	9.04	9.42
YWL (tons/Ha/year)	8.86	8.78	8.96	9.04	9.04	9.04	9.20	9.35	9.51	9.68
YF	0.67	0.73	0.74	0.68	0.70	0.69	0.90	0.93	0.95	0.97
EQF	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52
BC (gha)	**95,760.00**	**105,340.50**	**107,630.25**	**97,974.98**	**101,606.15**	**98,234.36**	**132,183.27**	**137,002.04**	**140,753.52**	**144,198.35**
P (tons)	446,743.00	480,258.00	422,051.89	462,090.48	475,767.18	448,109.84	476,209.68	496,672.17	517,134.67	537,597.16
YNL (tons/Ha/year)	5.89	6.40	6.62	6.15	6.37	6.22	8.32	8.65	9.04	9.42
YF	0.67	0.73	0.74	0.68	0.70	0.69	0.90	0.93	0.95	0.97
EQF	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52	2.52
EF (gha)	**127,070.77**	**137,879.71**	**118,720.25**	**128,766.25**	**132,577.41**	**124,870.41**	**130,450.54**	**133,862.45**	**137,032.53**	**139,952.98**
LCC	**0.75**	**0.76**	**0.91**	**0.76**	**0.77**	**0.79**	**1.01**	**1.02**	**1.03**	**1.03**
Status	**Deficit**	**Deficit**	**Deficit**	**Deficit**	**Deficit**	**Deficit**	**Balanced**	**Balanced**	**Balanced**	**Balanced**

5 Discussion

The findings in the case study showed that not all determinants could attract the agricultural land conversion. Many studies found that the expansion of road infrastructure can have a direct and indirect impact and also could accelerate the land conversion [26,27]. However, not all type of the roads can lead to significant change of the agricultural land conversion. In a study conducted in Jogja, it was known that a strong correlation was observed between the agricultural land conversion and the distance to the major roads, in that case in the forms of ring road and main roads [28]. That study supports our finding that showed only small decrease of agricultural land in the scenario 1, included only determinants of existing road infrastructure and building density with the domination of around 80% of the road networks are local roads and not the major roads.

As Jombang District is not a part of a metropolitan area in the East Java Province, therefore the level of urbanization in the region is not prominent. This is indicated by the low percentage of built-up area (only 21.43% of the total area in 2022), the centres of the activities only serve for the local and internal scale, and industrial areas only takes about 1.5% of the total area. This is supported by a similar study regarding the spatial pattern of agricultural land conversion in the West Java Province [29]. The study found that the rate of conversion on the agricultural land varied widely with the pattern of high land conversion tend to concentrate in the cities and regions that are part of the metropolitan areas.

In the perspective of a spatial approach, securing the land by establishing the status of the land as the “non-convertible” land can be a hugely influential tool to maintain the agricultural land. This policy is already established and implemented through the Law Number 41 of 2009 on Sustainable Food Agricultural Land (LP2B) [30] and the Presidential Regulation Number 59 of 2019 on the Controlling of Paddy Field Conversion [31]. As the protection of land should be conducted in a series process of planning and determining, developing, guiding, controlling, and monitoring the land and its surrounding, hence the protection strategies are needed not only on the level of the written regulation but also in the role of practicality [32]. The strategies for protection and control should focus on safeguarding agricultural land and areas, ensuring the land's continued existence, achieving food security, and protecting the rights of landowners that includes providing farmers with access, empowering them, and maintaining ecological balance [32].

In line with the slow rate of the agricultural land conversion in Jombang District and increasing area of the agricultural land if the policy on LP2B is successfully implemented, the status of the LCC in the study area reveals with a tendency to balanced and/or towards surplus in the future. Apart from the land as one factor, total of annual production also contributes to the positive trend of the LCC. This is caused by the joint effort between the government levels.

East Java Province is one of the food estates in Indonesia and Jombang District significantly contributes as one of the food barns in the East Java Province [33]. In terms of paddy field productivity, in 2022 Jombang District was ranked in 7th position amongst 38 regions in the East Java Province [8]. With this potential and strategic position, Jombang District has established programs to increase agricultural productivity. Not only from the local government itself, there also have been notably collaboration, coordination, and synergy between the local government of Jombang District, Provincial Government of the East Java, and central government in sustaining the agricultural production and productivity.

The agricultural agency of the Jombang District established the following strategies in order to overcome and/or anticipate the challenges of changing climate, decreased land carrying capacity, decreased area of agricultural cultivation, and environmental pollution

[21]: (1) increasing the capacity of human resources and farmer institutions through training for women farmers and young farmers group as well as forming farmers' owned enterprise; (2) building and maintaining agricultural infrastructure such as farm/agricultural roads and irrigation networks (up to 80.45% of the agricultural land has been covered by the irrigation system); (3) increasing the availability of farming equipment and production facilities such as 2 and 4-wheeled tractors, rice transplanter, combine harvester, water pumps, rice seeds and liquid organic fertilizers; (4) controlling pests and plant diseases.

6 Conclusion

Amongst all determinants that have been reviewed, it is found that in the case of Jombang District, the aspect of urbanization, industrialization, and regional infrastructure did not generate significant impact on stimulating the agricultural land conversion as the urbanization phenomenon is not too prominent, industrialization areas only take very small part (1.5%) of the total area, and around 80% of the road networks are categorized as the local roads that serve only for local and internal activities. Positively, this resulted to a quite stagnant change of the agricultural land from 2022 to 2043 prediction in scenario 1 and 2. On the other side, the agricultural policy and plan in the forms of Sustainable Food Agricultural Land (LP2B) and agricultural areas in the spatial plan are able to maintain and protect the agricultural area in the future if successfully implemented. Thus, in scenario 3 which incorporated all determinants including the agricultural policy and plan, the increase of agricultural land can be observed up to 3.72% in 2043 compared to 2022. Those formerly mentioned dynamics contribute to the LCC calculations with findings as follows: deficit status of LCC happened during 2017-2022 yet it is forecasted that balanced status (towards a surplus status) of the LCC for all scenarios will be experienced by Jombang District in 2028-2043. A key factor affecting the increasing status of the LCC is the increased productivity caused by the increasing trend of agricultural production as the positive impacts of the synergy on agricultural programs between the local, provincial, and central government.

The status of LCC is significantly affected by the land availability. Based on the findings, policy on the land agricultural protection is essential and can be a significant anchor to hinder the agricultural land conversion in the future. Nevertheless, the implementation and practice on controlling the LP2B is still lacking. Therefore, potential direction for further research is to formulate the framework of incentive and disincentive of the LP2B based on the perspective of the agricultural landowner. Moreover, from the methodological approach, other scenarios can also be simulated using different methods Logistic Regression (LR), Weight of Evidence (WoE), and Multi-Criteria Evaluation (MCE) in calculating and predicting the agricultural land conversion.

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