Sustainable Agricultural System : Linking Food Supply And Land Conservation

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ABSTRACT

The conversion of rice fields is increasingly difficult to control, as it continues in line with population growth and the expanding demand for economic and infrastructure development, thereby posing a serious threat to food security. This study aims to analyze the factors driving agricultural land conversion, assess trends in rice demand in Badung Regency up to 2030, and formulate strategies to enhance food availability. The research was a qualitative descriptive approach using secondary data. The data included agricultural land area, harvested area, production values, and population statistics over a ten-year period. Principal Component Analysis (PCA) was used to identify the factors influencing land-use change, while the levels of food availability by utilizing secondary data on rice commodity production and population numbers over the course of 10 yr (2012–2022). Badung Regency covers an area of 418.52 km², with a population of 549,530 in 2021. A rapid population increase occurred between 2020 and 2022, with an additional 1,340 people, which contributed to accelerated agricultural land conversion. The total area of rice field conversion in Badung Regency reached 276.60 hectares, with the highest conversion occurring in Mengwi District (136 hectares). The main driving factors of land conversion were economic pressures related to population growth and infrastructure availability. By 2030, the population of Badung Regency is projected to increase by 16.55%, from 585,392 people in 2022 to 682,313 people. Consequently, rice demand is expected to rise from 61,750.08 tons to 71,973.79 tons in 2030. Strategies to improve food availability focus on reducing land-use conversion through both legal and economic instruments.

1. Introduction

Land is one of the most important elements supporting the continuity of human life. It serves as a space for various human activities [5;7]. However, along with population growth and the development of human civilization, land resources have increasingly experienced degradation. This condition is a consequence of rapid population growth, technological advancement, and dynamic development processes. Land that was originally suitable for agricultural purposes has gradually been converted into residential areas and other non-agricultural uses [8;9]. This shift reflects a broader change in land utilization from agricultural to non-agricultural functions.

The continuous increase in population and development activities has led to a significant reduction in productive paddy land [1]. This situation has resulted in declining food production, causing food availability to decrease and become increasingly unbalanced with population demand.

Food production is influenced by various factors, including climate conditions, land characteristics, rainfall, irrigation systems, agricultural production inputs, and farmer incentives [2].

As a rapidly developing region driven by tourism growth, the conversion of agricultural land in Badung Regency has become increasingly difficult to control. Land-use changes from ecological and agricultural functions to built-up areas are most prominent in South Kuta District, Kuta District, and North Kuta District. Furthermore, land conversion has begun to expand into other sub-districts, including Mengwi, Petang, and Abiansemal Districts [3].

Land-use change is difficult to prevent, particularly when development policies prioritize economic growth [8;10]. If this trend continues, land conversion will generate serious negative impacts on food security [6;11], environmental sustainability [4; 8], employment opportunities, and social conditions [2;9]. Therefore, government policies aimed at addressing this issue should focus on minimizing these adverse impacts [4].

Based on these conditions, this study seeks to address the following research questions: a) What are the main factors driving land-use change. b) What is the current availability of agricultural land and rice in Badung Regency, and c) What strategies can be implemented to reduce land-use change.

Accordingly, this research aims to analyze the factors causing land conversion, examine trends in rice demand in Badung Regency up to 2030, and formulate land conservation strategies to support sustainable agriculture

2. Method

The research was qualitative and descriptive using secondary data in the form of data on agricultural land area, harvest area, production value, and population over ten years (2012-2021). Data were collected from field study and direct observation, and were described with the aid of figures and tables. Factors causing changes in land function used Principal Component Analysis (PCA), and population projections in 2030 was used exponential growth methods.

The level of food availability is calculated based on the ratio of normative consumption to the net production of paddy commodities. Calculation of the net food production using the formula:

P Net = P – P (s + f + w).

where: P Net = net production, P = actual production, s = seed conversion value, f = feed conversion value, and w = scattered conversion value.

The ratio of normative consumption to food availability based on net production value shows the level of food adequacy. The ability to provide pagan materials is determined according to Kurniawan (2015) based on the following formula:

I.av = F/C-norm

F = P/(T pop x 365)

Where: I.av = food availability ratio; C-norm = Normative consumption rice (289 gr/capita/d); F = Availability of cereal food (gr/capita/d); P = Production of rice (g); and T pop = Number of Population (person).

3. Results and Discussion

A. Land Use Change and Driving Factors

Change of paddy fields from 2018-2022 are presented in Table 1

Table 1. Displace Farm Function of Paddy Field by Subdistricts (Hectare), 2018-2022

Subdistricts	2018	2019	2020	2021	2022
Kuta South	-	-	-	-	-
Kuta	3.00	1.00	-	-	-

Kuta North	137.34	37.81	8.99	10,810	135.60
Mengwi	144.00	0.200	17,040	61,000	136.00
Abiansemal	28.94	-	-	0.90	-
Petang	10,00	-	-	-	5,00
Total	**323,28**	**39,01**	**26,03**	**72,710**	**276,60**

Source: Badung Regency in Figures 2023

Tabel 1 shows the total conversion of paddy fields in Badung Regency in 2018-2022. The total land use change in 2022 was 276.60 hectares. Most of the land conversion in Mengwi District was 136 hectares.

The Principal Component Analysis (PCA) show that of the 100 respondents analyzed fulfil data adequacy (Table 2).

Table 2. KMO and Bartlett's Test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.497
Bartlett's Test of Sphericity	Approx. Chi-Square	9,480
	Df	6
	Sig.	0.148

Table 2 shows the KMO and Bartlet's test values are 0.497 or rounded becomes 0.5 which means that four variables used in study this worthy analyzed. Analysis results show, from four variable factor pusher change function land agriculture two factors are formed together (Table 3). Common factors one that is aspect economy with percentage variance = 31,580 and factor together two viz aspect infrastructure with percentage variance = 28,605 as well cumulative percentage variance from both factors together amounting to =31.580% and 60.185% (Table 3). Economic aspects and aspects infrastructure considered give donation biggest to change function land because to two aspects the with total initial eigenvalue ≥ 1 (Table 3).

Table 3. Initial Eigenvalues

No Variable	**Total**	**% of Variance**	**Cumulative %**
1. Economy	1,263	31,580	31,580
2. Infrastructure	1,144	28,605	60,185
3. Policy	0,878	21,960	82.145
4. Institutional	0,714	17,855	100,000

Each factor in Table 3 above own encouraging influence resident local For develop activity tourism , so can impact change function land , so the most of the land conversion in Mengwi District was 136 hectares.

As depicted above, agriculture sector in Badung Regency is facing problems and challenges that are not light. Problem It's very complex and it's not stand alone. It's fast current switch function land agriculture is consequence from multi- dimensional problems. The main factor that can become reason switch function land was:

1) Availability infrastructure economy is factor positive dominant influence to internal investor preferences choose location land to be built for outside activities agriculture. The infrastructure in a way general more available in the area existing agriculture develop consequence past development. The consequences is request land by inclined investors more

high in the area existing agriculture developing, especially those approaching target its consumers like in the area fringe city [8]. Consideration aspect economy in development activity tourist cause lots resident switch profession to the tourism sector because assume business in the sector tourist more favorable in comparison business in the field agriculture [2;5].

2) Protection government to land agriculture productive relatively weak. Condition thereby can happen consequence market assessment of land inclined agriculture under estimate because land agriculture considered only produce commodity valuable agriculture cheap and valuable plus low [8]. Perception thereby attached to almost all over layer public including the perpetrators economy macro. This matter reflected in GDP, growth is measured only from mark production agriculture in a way physique. Agricultural land has a very wide multi functionality in a way environmental and social. Perception so does what causes it conversion land agriculture often taking place with support bureaucracy area with reason For push growth economy area.
3) The internal side of public which can stated as pusher happen switch function land agriculture, including :
    a. Income from farming no enough for life worthy except the land for sale or rented For non- agricultural use
    b. Most of farmer > 50 years old
    c. Productivity stagnant paddy fields (5.6 tons/ha)
    d. Wide cultivated the more narrow because fragmented with exists culture.
    e. Availability of irrigation water decreased.
    f. Weakness protection law.
    g. Increasing price land consequence he woke up network infrastructure supporters and continues stimulate other farmers joined in sell the land.

3.2 Land Potential and Rice Needs in Badung Regency

Badung needs it diversification field business for reduce high dependency to tourist. In order to set priority field effort that will encouraged, required identification sector superior. Primary sector (agriculture in the broadest sense) is sector upstream being provider material standard for sector industry based agro and own role important in economy. In 2020 contribution category agriculture to economy Badung Regency was 7.60 percent and will be 8.50 percent in 2021. Trend enhancement contribution category Agriculture This caused Because happen shift contribution category others are inclined experience decline as consequence exists COVID-19 pandemic.

Existing rice field area in Badung Regency in 2020 was 13,629 Ha, the wide largest in the District Mengwi, followed Abiansemal district, Petang and North Kuta, with commodity rice and secondary crops as a leading sector beside farm like pigs and cattle, also small industrial and craft house ladder. In Badung Ragency, the amount subak was 116, with the bigest amount was in Abiansemal district. The potency of subak was in field economics, in particular tourism, capable give a double impact.

Existing rice fields need to be managed into sustainable agricultural land. In Law of the Republic of Indonesia Number 41 of 2009 [12], concerning Protection of Sustainable Food Agricultural Land. Sustainable Food Agricultural Land is an area of agricultural land that is designated to be protected and developed consistently to produce staple food for national food independence, resilience and sovereignty. Meanwhile, sustainable food agricultural land protection is defined as a system and process for planning and determining, developing, utilizing and fostering, controlling and monitoring food agricultural land and its areas in a sustainable manner. In line with [14], the Regent of Badung has determine the map and distribution of sustainable food farming land with No: 382/048/HK/2022 with amount designated land, amounting to 6,656, 32 Ha with details: North Kuta District 337.46 Ha, Mengwi 3,268.69 Ha, Abiansemal 2,348.78 and Petang District 701, 39 Ha.

Availability food is subsystem resilience food and roots from effort point out independence and sovereignty food. Availability food is condition availability food from results production domestic and reserve food national as well as import if second source main No can fulfil need. Main

capital in realize availability food is riches source diverse power, availability, technology, and development partnership strategic with various component holder [11].

Food production depending on the variety factor like climate, type of land, rainfall, irrigation, inputs, and even incentive for farmers [11].

Table 4. Harvested Area, Production and Productivity of Rice in Badung Regency in 2018-2020

Harvest Area, Production, and Rice Productivity	**Harvested Area, Production and Productivity of Rice in Badung Regency**		
	2018	**2019**	**2020**
Harvested Area (ha)	17700.00	12943.13	13629.00
Production (tons)	109583.00	85475.63	83587.00
Productivity (quintal/ha)	61.91	66.04	61.33
Rice Equivalent Production (tons)	61482.00	47956.14	46897.00

Source Url:https://badungkab.bps.go.id/indicator/53/215/1/lebar-panen-produk-dan-produktif-padi-di-kabupaten-badung.html
Access Time: February 24, 2023, 12:38 pm

Based on this data for sufficient need wide harvest for residents in the Badung regency can calculated with formula as follows :

$$\text{Requirements for harvest area (ha)} = \frac{\text{Rice needs (kg/capita.year) x Total population}}{\text{Productivity (kh/ha) x Conversion unit of milled dry grain to rice}}$$

The calculation results of need normative rice and necessities wide harvest, for the population in Badung Regency is presented in Table 5

Table 5. Needs normative rice and necessities wide harvest, per Districts in Badung Regency in 2020-2021

Subdistrict	**2020**			**2021**		
	Amount Resident	***Need Normative Rice (kg-yr)***	***Harvest Area Requirements (ha)***	***Amount Resident***	***Need Normative Rice (kg-yr)***	***Harvest Area Requirements (ha)***
South Kuta	131100	13829083.50	3601.44	131400	13860729.00	3609.69
Kuta	59200	6244712.00	1626.28	59300	6255260.50	1629.03
North Kuta	95200	10042172.00	2615.24	95400	10063269.00	2620.73
Mengwi	132800	14008408.00	3648.15	133100	14040053.50	3656.39
Abian Semal	98900	10432466.50	2716.88	99100	10453563.50	2722.37
Petang	31000	3270035.00	851.60	31100	3280583.50	854.35
Total	548200	57826877.00	15059.59	549400	57953459.00	15092.55

Note: Requirement Normative Rice 289 gr/ cap / day or 105.49 kg/ cap / year (WNPG XI, 2018)
Badung Regency Rice Land Productivity in 2020 is 61.33 kw GKG/ha [3]. SKGB (Unit Conversion of Milled Dry Grain to Rice) for Bali 62.61 % [13]

The Growth rate Resident from 2012 to 2019 was 2.21%. Based on calculation, the trend of rice demand in the Badung Regency presented in Table 6.

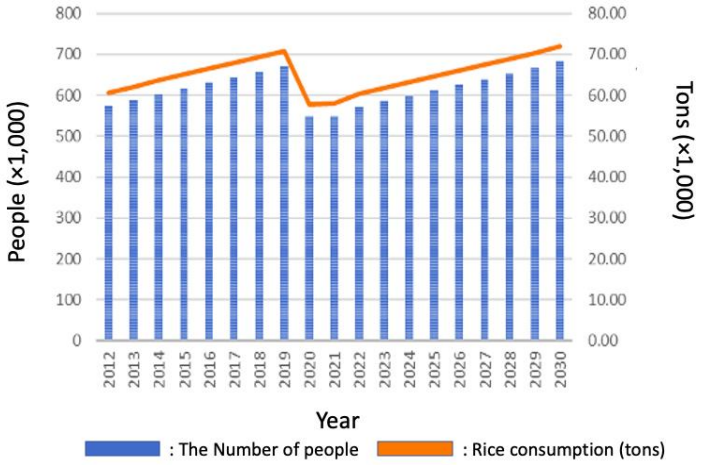

Fig 1. The trend of rice demand and the number of people in the Badung Regency from 2012 to 2030

Figure 1 shows, the population of Badung Regency is projected to increase by 16.55%, from 585,392 people in 2022 to 682,313 people in 2030 and rice demand is expected to rise from 61,750.08 tons to 71,973.79 tons in 2030.

3.3 Strategies for Agricultural Land Protection

Several strategies can be proposed to strengthen agricultural land protection in Badung Regency. Badung Regent Regulation No. 382/048/HK/2022 [14] designates a total of 6,656.32 hectares as protected agricultural land, comprising 337.46 hectares in North Kuta District, 3,268.69 hectares in Mengwi District, 2,348.78 hectares in Abiansemal District, and 701.39 hectares in Petang District. Effective implementation of this regulation requires consistent law enforcement supported by the fair and sustainable application of incentive and disincentive mechanisms.

Incentives granted to farmers will be withdrawn if designated agricultural land is converted to non-agricultural uses in violation of the regulation. The withdrawal process will be implemented progressively, beginning with written warnings, followed by reductions in incentives, and ultimately full revocation. Incentives for agricultural land protection may include land and building tax relief, investment in agricultural infrastructure, provision of production inputs, improved access to information and technology, and recognition of high-performing farmers and farmer organizations. These incentive mechanisms should be formally regulated through a Regent Regulation. In the absence of such regulation, incentives for land designated as Sustainable Food Agricultural Land cannot yet be operationalized [12].

Complementary strategies include integrating agricultural activities with other local economic sectors, particularly through the development of agrotourism and ecotourism, which can enhance the economic value of agricultural landscapes while maintaining land use functions.

Additional economic incentives may be implemented through programs supporting the production of organic or healthy rice. Under this scheme, farmers are encouraged to adopt organic farming practices by minimizing or eliminating chemical fertilizers and pesticides. During the initial transition period, production inputs—such as organic fertilizers, seeds, and planting costs—should be subsidized by the government until farming operations become economically stable. Public financial assistance is intended to function as revolving capital, subsequently allocated to farmers who have not yet received support.

Harvested products will be purchased by business partners at prices above prevailing market rates. This program aims to increase paddy farmers' incomes, strengthen farmer self-reliance,

promote environmentally sustainable agricultural practices, and improve the availability of healthier food products.

Several strategies are possible offered for as giving incentive is as follows:

a. On protected rice fields or sustainable food farming land with amount designated land amounting to 6,656, 32 Ha with details: North Kuta District 337.46 Ha, Mengwi 3,268.69 Ha, Abiansemal 2,348.78 and District Evening 701, 39 Ha necessary given incentives. Giving Incentive to farmer is something effort for increase quality of human resources in agriculture. Source power man agriculture is very necessary to use increase results and quality production agriculture . With exists incentive source fower man agriculture so farmer capable innovate create technology capable agriculture produce product quality agriculture is also deep high quantity, so capable fulfil need will food in a way national even international.
b. Government will do retraction incentives, if farmer as recipient incentive no do his obligations with no do protection of its sustainable food agricultural land, with violate norms, standards, procedures and criteria, as well as if the land has converted. Revocation incentive worn in a way gradually with through giving warning written, subtraction giving incentives, and revocation Incentive.
c. Giving incentive to owner land agriculture will push they for protect and repair their land agriculture. When given stimulation, some big farmer choose for still maintain land his farm. Farmer need incentive because farmer own and manage land agriculture productive. The more wide land agriculture, increasingly income also increases owner land.
d. Form incentive for group farmer achievement given in form tools and machines agriculture, means production agriculture, facilities and infrastructure irrigation, and or other awards are being considered as form incentives. Incentive the should arranged in form of Regent Regulation. Throughout not yet there is Regent Regulation is in charge about incentive that, then incentive to farmer whose land set as sustainable food agricultural land. Not yet can held. should after there is determination land farmer as Sustainable Food Agricultural Land (LP2B), then incentive must given. For that urge for area for quick arrange provision about incentive so that incentive quick can given to farmers who obey the provisions regulation legislation with no convert land agriculture become non-agricultural.
e. Another effort is synergizem activity agriculture with activity economy other communities, for example with synergy between agriculture and tourism for agrotourism activity. Utilization land agriculture for tourist can implemented in existing areas set as sustainable food agricultural land for use add well-being public farmer.

4. Conclusion

1. The total area of rice field conversion in Badung Regency reached 276.60 hectares, with the highest conversion occurring in Mengwi District (136 hectares).

2. The main driving factors of land conversion were economic pressures related to population growth and infrastructure availability.

3. By 2030, the population of Badung Regency is projected to increase by 16.55%, from 585,392 people in 2022 to 682,313 people. Consequently, rice demand is expected to rise from 61,750.08 tons to 71,973.79 tons in 2030.

4. Strategies to improve food availability focus on reducing land-use conversion through both legal and economic instruments.

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