Agricultural Land Carrying Capacity and Shift of Land Use in Upstream of Grompol Watershed, Central Java Province

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Abstract. This research was conducted in the upstream of Grompol watershed. This study aims to identify: 1) the changes of agricultural land carrying capacity, and 2) the shift of agricultural land use. Primary data of the research were obtained from field observation to know land use in Grompol watershed, while the secondary data were obtained from various stakeholders that were in accordance with the required data. The result of data analysis and data interpretation, it can be known that: 1) the agricultural land carrying capacity in Grompol watershed is in deficit state. In 2003, Karang is the only village that is surplus, while in 2007 and 2014 both Karang and Tohkuning experienced a deficit; 2) the shift of agricultural land use in the upstream of Grompol watershed sampled by Karang and Tohkuning village in 2000, 2007, and 2015 shows that the paddy fields and unirrigated field turned into settlements. During the last sixteen years, the agricultural land in the upstream of Grompol watershed has decreased about 15.68 ha.

1. Introduction
Indonesia is an agrarian country which most of its people working in agriculture sector. The most important sector is agriculture which means farmland is the essential for their living. Recently, farmland where the farmers do their activities has increasingly decreased. This condition is due to the increasing population need towards the agricultural land. As a result, the capacity of the agricultural land to occupy the food supply is decreasing. Reference [1] shows that such condition leads into the fierce competition of land use. The competition is intended to get the land for settlement, business center, and public infrastructure. When the competition is out of control, it will lead to environmental degradation, especially the decline in the quality of agricultural land. Currently, Indonesia has tried to achieve self-sufficiency in food. However, the agricultural land portion continues to be declined. Reference [2] suggests that the sustainable agriculture is highly dependent on the use of important attributes of the agricultural matter. These attributes are related to the level of agricultural land use. Furthermore, it is also related to international trade conventions and to the mechanism of agricultural products distribution globally.

For centuries, human activities have changed the earth surface to produce food through agricultural activities. The land degradation will occur if the management system is inappropriate. Then, it also has a high risk to agricultural sustainability [3]. The decreasing land carrying capacity is influenced by the overwhelming population growth, the decreased land area, the percentage of farmers, and the provided land for the proper living area [4]. The population density keeps increasing and human undertake developmental activities. Both factors have taken over the real function of agricultural land as food producer and food supplier. Now, the agricultural land has been turned into other functions, such as...
settlements, office buildings, and so on. Reference [5] states that the higher the population density the higher the level of demand for land. This situation is highly contradictory with the condition that population growth brings consequences of increased food demand and food availability which important needs in life. Reference [6] explains that the higher the population density the higher the level of demand for land. If such condition occurs continuously, there is possibility that the food production is not balanced to the food demand by the population caused by agricultural land carrying will be decreasing.

Efficient and responsible utilization are the essential factors in managing and developing lands [7]. In addition, the planning of food supply for public consumptions is another important part in order to achieve food availability. Reference [8] explains that food security is an integrated system which consists of various subsystems. The main subsystem is food availability, food distribution and food consumption. To achieve food security, we need synergy of the interaction among the three subsystems. Food security has been controlled in national Law number 18, 2012. The law covers the fulfillment of food for the national level up to the individual level in the country, which can be seen from the availability of adequate food quantity and quality, safe, diverse, nutritious, equitable and affordable and not be in conflict with religion, belief, and culture, which intended to be able to live healthy, active, and productive in a sustainable condition [9].

Analysis of agricultural land carrying capacity and shift in using is necessarily to be undertaken since it is important to determine the land capacity in providing food for the fulfillment of the needs of the population in certain area. The analysis of environmental carrying capacity is done by analyzing the level of productivity. Thus, it is carried out by comparing the availability of land and land demand in fulfilling the needs of regional biological products [10]. By using this method, it can be seen the overview whether the land carrying capacity of a region is in a state of surplus or deficit. Surplus is indicated by the capacity local land in occupying the need for biological products. On the other hand, deficit is indicated by incapability of local land to supply the biological products for the region.

In this case, watershed area is very beneficial for the surrounding people. The society can utilize the area to develop agricultural activities since the availability of hydrology and fertile lands support them to get the maximum agricultural productivity. Thus, population growth and inter-regional development is rapidly increased around the watershed. It may lead to the high land demand and cause the land use conversion and land use pattern become less efficient. If the pressure exceeds its carrying capacity, the land degradation will occur, such as floods, erosion, landslides and the other kinds of environmental loss. [11]

The shift of land use results in majority of lands is used inappropriately with its carrying ability. As a result, it brings effects to the carrying capacity of land and land quality. Reference [12] indicates that shift of land use in watershed areas results in the loss of forest into other land uses which having limited environmental carrying capacity so that floods and droughts are more frequent. Reference [13] explains that basically, a good land use should be in line with the land capacity so that the land carrying capacity is also good. Since the land has a certain level of capacity to support human life, the land used in accordance with its ability is also able to reduce the level of risk of environmental loss. As a result, the land can be use sustainably.

Regarding the agricultural land carrying capacity in the watershed, it is it is necessary to do analysis so that the conversion of agricultural land into the developed land is under control. The ecosystem in the watershed area is very important part as protection for itself. Upstream river basin ecosystem has a function of protection of the watershed, among others in terms of water function, for instance water management function. Therefore, planning for upstream watershed is mainly considered as the focus of planning, since both upstream and downstream areas have biophysical interaction within the hydrological cycle [14]. This article will mainly discuss about the agricultural land carrying capacity and the shift of land use in the upstream of Grompol watershed.
2. Methods
This research was carried out in the Grompol sub watershed which is administratively located in Karanganyar and Sragen regency, Central Java. The samples of this research were chosen by applying purposive sampling technique. The samples are the two largest villages, Karang and Tohkuning village. The data used for analysis consist of population data, administrative map data and land use map, rice price data. In addition, data in this research were obtained through observation and documentation study. Then, the data were analyzed descriptively quantitative then described to answer the research problems.

2.1. Shift of land use
The shift of land use is known by the icons image overlays which analyzed with ArcGis 10 and validated by field surveys.

2.2. Land carrying capacity
The carrying capacity of the land is calculated according to the Regulation of Indonesian Ministry of the Environment Number 17, 2009, to determine the carrying capacity of the land from a region. The calculation is carried out as the following stages:

2.2.1. Calculation of land supply with the following formula:

\[
SL = \frac{\sum (Pi \times Hi)}{Hb} \times \frac{1}{Ptvb}
\]

Note:
SL = Land availability (ha)
Pi = Actual production of each commodity type (the unit is dependent on commodity type). The commodity includes agriculture, plantation, forestry, livestock and fishery.
Hi = Price of each commodity type (Rp/Unit) at producer level
Hb = Rice unit price (Rp/kg) at the producer level
Ptvb = Productivity of Rice (Kg/ha)

2.2.2. Calculation of land demand with the following formula:

\[
DL = N \times KHLL
\]

Note:
DL = Total of land demand equivalent to rice (ha)
N = Number of people (people)
KHLL = Land demanded for decent living needs per individual:
- The amount of land demanded for decent living needs per population is a proper living need per population divided by the productivity of local rice.
- The need for proper living per population is assumed to be 1 Ton equivalent of rice/capita/year.
- The areas which do not have data on local rice productivity can use national average rice productivity data of 2400kg/ha/year.

2.2.3. Determining the status of land carrying capacity. Land carrying capacity is derived from the comparison between land availability (SL) and land demands (DL).
- If SL > DL, the carrying capacity of the land is considered as surplus.
- If SL < DL, the carrying capacity of the land is considered as deficit.
3. Results and Discussion
The results of this study show the level of agricultural land changes in the upper watershed Grompol and the level of carrying capacity in order to fulfil the food demands of the community. Based on the data that has been analyzed, it can be drawn an overview of the condition of land and its carrying capacity towards food security in the upper watershed Grompol.

3.1. The shift in agricultural land use in upstream of Grompol watershed

3.1.1. Karang Village. Karang village is a village with total population of 3951 inhabitants in 2014. Administratively, Karang is adjacent to Puntukrejo village, Berjo village, Plumbon village, Salam village and Gerdu village. Land use in Karang village over the past fifteen years has been compiled into three land use maps in 2000, 2007 and 2015. Land use in the reef villages is in Table 1.

| No | Land Use (Karang Village) | Width (Ha) | Changes (Ha) |
|----|--------------------------|------------|-------------|
|    |                          | 2000       | 2007       | 2015       |            |
| 1  | Houses                   | 79,87      | 87,04      | 7,17       |            |
| 2  | Rice Field               | 163,13     | 155,96     | -7,17      |            |
| 3  | Unirrigated rice field   | 0,07       | 0,07       | 0          |            |
| 4  | Garden/plantation        | 13,4       | 13,4       | 0          |            |
| 5  | Unirrigated farmland     | 0,68       | 0,68       | 0          |            |
|    | Total                    | 263,57     | 263,57     | 263,57     |            |

3.1.2. Tohkuning Village. Tohkuning village has total population of 4,877 inhabitants in 2014. It is administratively located in border to Gondangmanis, Dayu, Karangpandan, Bangsri, Ngamplak, Sewurejo and Delingan. Land use in Tohkuning village is divided into three land use maps in 2000, 2007 and 2015. Land use in Tohkuning village is in Table 2.

| No | Land Use (Tohkuning Village) | Width (Ha) | Changes (Ha) |
|----|-----------------------------|------------|-------------|
|    |                             | 2000       | 2007       | 2015       |            |
| 1  | Houses                      | 247,95     | 256,46     | 8,51       |            |
| 2  | Rice Field                  | 152,5      | 143,99     | -8,51      |            |
| 3  | Garden/Plantation           | 77,54      | 77,54      | 0          |            |
| 4  | Unirrigated farmland        | 30,52      | 30,52      | 0          |            |
|    | Total                       | 508,51     | 508,51     | 508,51     |            |

3.2. Agricultural land carrying capacity in upstream of Grompol watershed

3.2.1. Karang Village. Land carrying capacity is obtained from the comparison between land availability and land demands. Calculation of land carrying capacity in Karang village in 2003, 2007 and 2014 can be seen in table 3 below:
### Table 3. The Changes of Land Carrying Capacity in Karang in 2003-2007-2014.

| No | Year | Availability | Demand | Availability/Demand | DLL |
|----|------|--------------|--------|---------------------|-----|
| 1  | 2003 | 1.340.6      | 1.104.2| 1.2                 | Surplus |
| 2  | 2007 | 917.6        | 1.149.4| 0.8                 | Deficit |
| 3  | 2014 | 919.1        | 1.070.1| 0.9                 | Deficit |

3.2.2. Tohkuning Village. Land carrying capacity is obtained from the comparison between land availability and land demands. Calculation of land carrying capacity in Tohkuning village in 2003-2007-2014 can be seen in Table 04.

### Table 4. The Changes of Land Carrying Capacity in Tohkuning in 2003-2007-2014.

| No | Year | Availability | Demand | Availability/Demand | DLL |
|----|------|--------------|--------|---------------------|-----|
| 1  | 2003 | 1054.6       | 1375.8 | 0.8                 | Deficit |
| 2  | 2007 | 1003.6       | 1434.8 | 0.7                 | Deficit |
| 3  | 2014 | 1064.6       | 1064.6 | 0.8                 | Deficit |

Based on the results of the research finding, it has given answers and a description of the extent to which the level of land use and the agricultural land carrying capacity in the upper watershed Grompol. The level of land demand and the land availability of a region should be in a balance. Reference [14] suggests that watershed management is a process of formulation and implementation of activities or programs that manipulate natural and human resources in the watershed area in order to get benefit for production and services without causing damage to water and soil resources.

Population growth continues to increase so that the existing agricultural land is targeted to be shifted into settlement land. Basically, food supplies are a key component of sustainable development. It is important to ensure that urban/residential development is undertaken on farmland, so that it can be prevented as far as possible [15]. If this case does not get special treatment from the government and from the local community, it is likely to occur that the function of agricultural land in the upper watershed of Grompol will change. Automatically, it has a major influence on the carrying capacity of the agricultural land. The balance between the utilization rate of land resources and the carrying capacity can be used as the feasibility measure of each development program. The development will be effective if the resource utilization is proportional to the carrying capacity of a region [16].

Based on Table 1, it is known that the area of Karang village is 263.57 ha, the use of land in Karang village covers: settlement/houses, rice field, rainfed rice field, garden/plantation, moor/field and vacant land. Throughout the year 2000-2015, land use which remains the same including, vast areas of rainfed, garden, moor, and vacant land. The use of land that is increased is 7.17 ha for settlements since the population growth is increased in the Karang village. There are developing settlements for private homes. Reduced land use is a rice field of 7.17 ha. References [17] states that infrastructure growth is a closely related to population growth. For an increasing population, it needs additional infrastructure. The use of rice fields is transformed into settlements to fulfil the demanded infrastructure. Along with the decreasing of the rice field, it is possible that the carrying capacity also changes because one variable of land carrying capacity is agricultural production.

Infrastructure development for modern life, housing, roads or other land developments is known as land sealing. When the land is sealed, the soil cannot perform much of its function as a rainwater absorber for infiltration and general filtration [18]. Based on the above explanation, it can be concluded that the land that has been built can no longer afford to contribute as water absorber, thus agricultural activity cannot be done anymore in the land. Then, the risk will give impact on the deficit of agricultural products. This condition does not only occur in Karan village but also in Tohkuning village. Based on table 2, it is known that Tohkuning village is 508.51 ha. The land use in Tohkuning village covers: settlement, rice field, garden/plantation and moor/field. Throughout the year 2000-
2015, the land use of a fixed area is a garden/plantation and moor/field. Then, land use which is extended is settlement of 8.51 ha as well as the increase in the number of residents. On the other hand, the reduced land use is a rice field of 8.51 ha. The use of rice fields is transformed into a settlement. Along with the decreasing of rice fields, the carrying capacity will also change.

The importance of carrying capacity is the ratio between availability and demand or supply and demand. This is important because supply is generally limited while demand is unlimited. Adequacy of agricultural productivity of each individual will never be known if observations and calculations are not undergone. References [19] suggest that towards the sustainable use of agricultural resources, either qualitatively or quantitatively from the relationship between land productivity, food production or grain production, the carrying capacity of the population and sustainable land resources should be tested. To know the change of carrying capacity of land in Grompol watershed, it is used the Regulation of Ministry number 17, 2009 about guidance of determination of environmental supporting capacity in spatial. Therefore, we can see that the two villages have the carrying capacity of the agricultural land which almost all of them have deficit. As it has been explained through the research result, only the Karang village in 2003 which is in surplus.

Land carrying capacity in Karang village during 2003 did not change with the surplus, while in 2007 and 2014 experienced deficit. This is because the area of Karang villages continues to decrease, so the limited availability of land whiles the great demands. The overall status of land carrying capacity in Karang village is a deficit.

A limited area of land and a large population will require a lot of crops to fulfil the needs of the community. On the other hand, the land is not able to provide sufficient results due to the extent of the day continues to diminish by the activities of residents who need land settlements such as the case of Tohkuning village. Most threats to land arise because land is used for various functions, at the same time and continuously. The utilization results in the emergence of an unstable system in which the land becomes incapable and vulnerable [18].

Based on Table 4, the carrying capacity of the land in Tohkuning village did not change from 2003 to 2014. The carrying capacity of the land is still deficit. One of the causes is the large population of Tohokuning and the perennial land that continues to be transformed into settlements. So, the land for agricultural activities to be limited and not able to give the result equal to the number of inhabitants in Tohkuning village. Over the last twelve years, the carrying capacity of land in Tohkuning village is a deficit.

4. Conclusions

Based on the above description, there are some conclusions to be considered as the following. The shift in land use in upstream of Grompol watershed based on samples of tohkuning villages and Karang villages in 2000, 2007 and 2015, the use of rice field is completely changed its function into a settlement. This change occurred in the two villages in 2007-2015. While in 2000-2007, agricultural land was still functioning. The highest change is in Tohkuning village which is 8.51 ha. The same thing happened in Karang villages to coincide in the year 2007-2015 the area of agricultural land of 7.17 ha in functioning into houses/settlement. The carrying capacity of land in upstream of Grompol watershed in 2003, 2007 and 2014 based on the sample indicates that the overall carrying capacity is deficit. Exceptionally, in 2003 only Karang village is surplus. In the case, Karang village experiences the carrying capacity of land deficit in 2007 and 2014. This situation is not only experienced by Karang village but also Tohkuning village. Tohkuning faces the worst level in the deficit of land carrying capacity. Based on research results, it shows that during 2003, 2007 and 2014 it has never experienced a surplus.

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