GROUNDWATER CONTAMINANT VULNERABILITY ANALYSIS OF ANTHROPOGENIC IMPACTS IN RURAL AREAS

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Abstract

Anthropogenic events are one of the sources of human activities that have an impact on environmental quality including the issue of groundwater contamination. This study emphasized analyzing the vulnerability of contaminants from agricultural events located in the Surabaya-Lamongan Groundwater Basin. The used method is passing through a structured interview approach with a specific purpose, then the results of it are analyzed using a descriptive statistical approach. The results obtained from the study are expected to illustrate the behavior of agriculture which is a combination of the understanding of farmers using water (both in surface water and groundwater). Those are related to fertilizer and pest eradication chemicals. Results of data analysis figure out a tendency to increase the intensity and volume of fertilizer and pest eradication chemical use in the early growing season. It indicates the potential for shallow groundwater pollution in the Surabaya-Lamongan Groundwater Basin. The results of this study are a starting point for research related to groundwater contaminants that are suspected to also be caused by human activities in the study area, it is because the study of contaminants that are more often done is about contaminants caused by industrial events.

Keywords: anthropogenic, agriculture, vulnerability, contaminant, hydrogeology

1. Introduction

Many agricultural sectors with the main varieties in the format of rice crops are a mainstay commodity for Indonesia, specificallyon Java Island.The request for paddy and rice as processed products for communal consumption is expanding in tandem with the community'sgrowing number of residents and the community'seconomic level is getting better. The Central Statistics Agency data (BPS, 2018) explains that the total rice needs in each province reached up to 23.9 million tons. East Java Province ranks second as regards rice needs, which is about 3.4 million tons (Pratama, et al., 2018). Meanwhile, in 2021,it was an enlarge in rice needs reaching 37.3 million tons with an average consumption value per capita within a week hitting 1.56 kg.This value for East Java Province is equivalent to 3.7 million tons (BPS, 2022).

One of the areas that became the main area of national rice development is in the northern coastal region of East Java, where the Surabaya-Lamongan Groundwater Basin is located (Energy and Mineral Resources Regulation No. 2 of 2017; East Java Provincial Regulation No. 12 of 2011; East Java Provincial Regulation No. 5 of 2012).The characteristics of the study area are restricted based on the Surabaya-Lamongan Groundwater Basin.This area is dominated by rice-palawijapaddy fields and land fishery ponds with surface water sources derived from rainwater and irrigation systems, as well as groundwater used for conjunctive use during the dry season in case of surface water conditions,are not suitable for use (BPS, 2020; Joubert et al., 2017; Sondhi, et al., 1989). This condition causes the need for groundwater support to become vital for farmers in the study area.This is supported by data that irrigation agriculture requires groundwater supply in various socio-economic conditions in each country (Chaudhuri et al., 2021; Jain et al., 2021; Bhanja et al., 2019; Burek et al., 2019; Seibert et al., 2010).On the other hand, the intensive use of various types of fertilizers and pest eradicating chemicals by farmers has the potential to have a serious impact on the surrounding environmental ecosystem including the local groundwaterquality.The speed of groundwater utilization by water-using farming communities around the world is suspected to affect the environment in various forms (Chaudhuri et al., 2021) in the form of limited water resources (Miro and Famiglietti, 2018; Chaudhuri and Ale, 2014a),salinization or contamination (Mastrocicco and Colombani, 2020; Najib et al., 2016; Chaudhuri and Ale, 2014b), seawater intrusion (Jasechko et al., 2020), land subsidence (Kadiyan et al., 2021; Meldebekova et al., 2020; Chauduri and Ale, 2013), air pollution (Bijay et al., 2008), and loss of ecosystem service power (Wada et al., 2012).

Pollution as a result of agricultural activities is mostly non-point source pollution.This type has the characteristics of the distribution of polluting sources not at one clear culmination point, but relatively scattered and generally follows geological conditions, hydrogeology, agricultural land area, frequency of fertilizers use and other chemicals, as well as the characteristics of pollutants.The relationship between surface water quality (rivers and lakes) with groundwater is closely related and affects each other.One of the efforts that can be made to minimize the impact of groundwater pollution is to prevent in advance heavy-scale pollution in rivers and lakes (Khan et al., 2022).Various human activities can have widespread implications in all areas of life in the form of emerging contaminants or abbreviated as ECs (Khan et al., 2019, 2022; Ouda et al., 2021; Gomes et al., 2018, 2020).The term emerging contaminants refers to the potential conditions of environmental disasters that will have a significant impact on the surroundings.Pollutants in the form of pesticides and fertilizers fall into the ECs category. Rathi et al (2021) stated that fertilizers and chemicals other than fertilizers are the main sources in the ECs category. When ECs are in the agricultural ecosystem environment, they will potentially be transformed through a typical mechanism in the form of groundwater pollution fate and transit mechanisms chemically, biologically, and physically (Choi et al., 2016; Kim et al., 2014; Hinkle and Tesoriero, 2014; Kumar and Riyazudin, 2012; Biswas et al., 2011; Appelo and Postma, 2005; Christensen et al., 2000; Barcelona et al., 1989).Then, the process will be transported into the form of food supply to the root system of the plant, transformation to the aquifer system, or transformation to surface water through precipitation or irrigation system (Khan et al., 2022; Khan et al., 2013; Boxall, 2012).Figure 1 shows the distribution cycle of various polluting sources involving different sectors of human life and the surrounding environment (Khan et al., 2022; Rasheed et al., 2019).

Khan et al., (2018) asserted that sources of pollutants in the soil, surface, and groundwater are supplied by the intensification of use of various fertilizer products and non-fertilizer chemicals.In India for example, during the period between 1970 and 1980 about half of the rice production produced led to an increase in fertilizer consumption (FAO, 2013). It also shows that the long-term use of fertilizer causes soil and water pollution that affects the level of human health and the deterioration of the aquatic environment quality (Almasri and Kaluarachi, 2004; Hanson, 2002; Hudak, 2000).Soil is generally polluted by heavy metal components (HMs) in the form of cadmium, mercury, arsenic, and others so it will potentially lower the pH of the soil. The indented thing also occurs in North America although at different levels and coupled with an increase in the concentration of Nitrate and Nitrite compounds (Robarge et al., 2004).In China, during the period 1980 to 2000 Guo et al., (2010) asserted that the main pollutants became a source of pollutants. They were caused by the use of nitrogen fertilizer product variants that polluted agricultural soils and were associated with biotic components.

This study is intended to find out the extent of potential pollution of anthropogenic activities, namely agriculture and ponds as a result of the use of fertilizers and pest exterminating chemicals that will affect the quality of the environment and groundwater.The main question in this study is how the planting patterns in the field (the first, second, and third planting patterns), and farmers' understanding of the stages in fertilization which consist ofan amount of fertilizer used, type of fertilizer, fertilization cycle, time-frequency of fertilization, chemicals other than fertilizers, and the harvest period.Levels of pollutant elements from fertilizers and chemicals other than fertilizers in the form of phosphates and ammonia as a representation of materials in agricultural fertilizers at the study site as well as some metallic elements such as aluminum, manganese, zinc, and copper are included in this analysis.

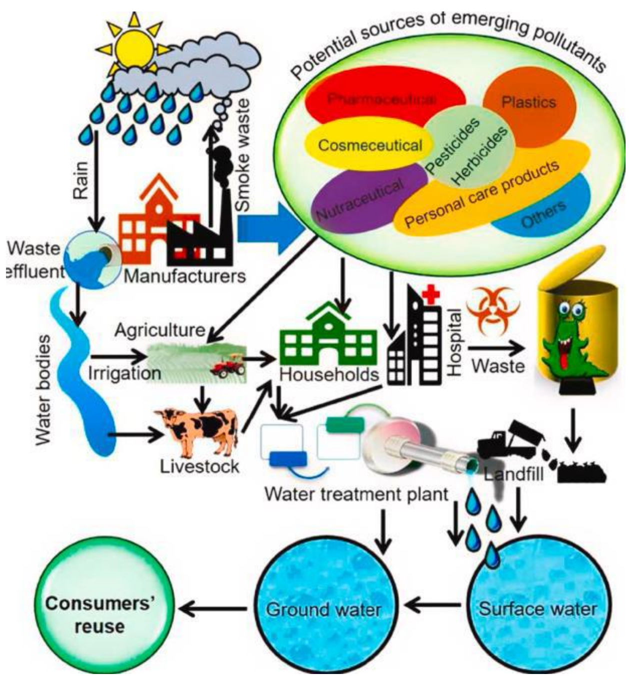

Figure 1. Distribution cycle of various polluting sources in various sectors of human life and the environment (Rasheed, 2019)

2. Materials and Methods

Study Location Description

The study location is the Surabaya-Lamongan Groundwater Basin area and is located on the northern coast of East Java Province.This basin administratively includes Bojonegoro, Lamongan, Tuban, and Gresik regencies as well as the west side of Surabaya City (Figure 2).This region is astronomically coordinated between 6°57′25.53″ S - 7°14′12.22″ S southern latitudeand 111°55′17.23″E-112°27′03.38″E east longitude. The region is affected by the tropical climate with an average annual temperature of 25.1°C.The average annual rainfall is 2,447.8 mm and about 77%-80% is concentrated during the rainy season affected by monsoon winds (BPS, 2022).

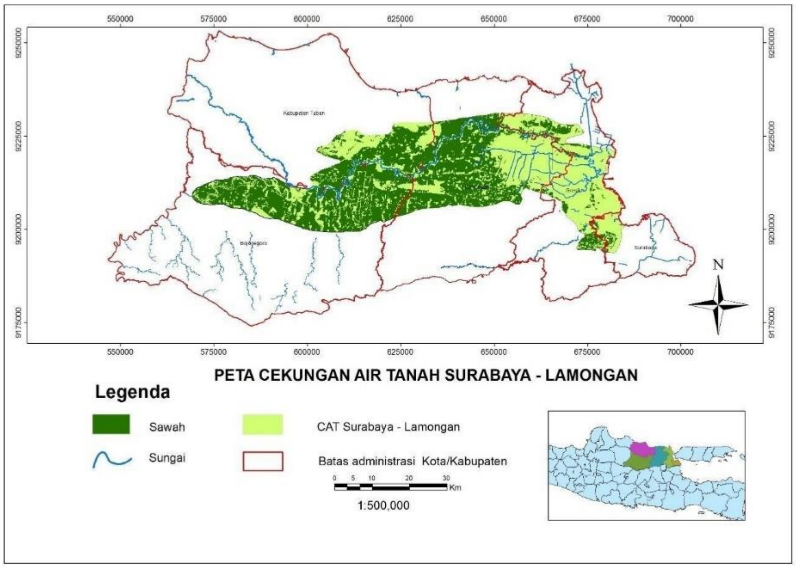

Figure 2. Location of Study Region

The area of the Surabaya-Lamongan Groundwater Basin is 219,356 ha. It is about 52% or an area of 113,526 ha is a rice field area with rice plants as the main commodity (Table 1).This shows that rice farming is the main leverage sector of agricultural development related to spatial utilization in the study area.

Table .1 Area of CAT and rice fields located in CAT Surabaya-Lamongan (Central Statistics Agency of East Java Province, 2020)

No	Regency / City	Groundwater Basin Area (ha)		Paddy field area into Groundwater Basin (ha)	
		Area per Regency/city (ha)	**% vs Groundwater Basin Area**	**Area per Regency/city (ha)**	**% vs Groundwater Basin Area**
1	Surabaya	5.823,20	2,7 %	1.010,56	0,5 %
2	Gresik	41.134,02	18,8 %	6.960,58	3,2 %
3	Lamongan	76.242,36	34,8%	40.831,72	18,6 %
4	Bojonegoro	61.661,41	28,1 %	44.658,06	20,4 %
5	Tuban	34.494,82	15,7 %	20.065,23	9,1 %
	Total	**219.355,81**	**100 %**	**113.526,15**	**51,8 %**

Geology and Hydrogeology

The geology of the study area is related to the physiographic zone of the North East Java Basin (Bemmelen, 1949; Pannekoek, 1949).The Surabaya-Lamongan Groundwater Basin is located in the Randublatung Zone which is bounded by the Java Sea in the north and a series of volcanoes with a west to east direction on the south side as figure 3 follows.

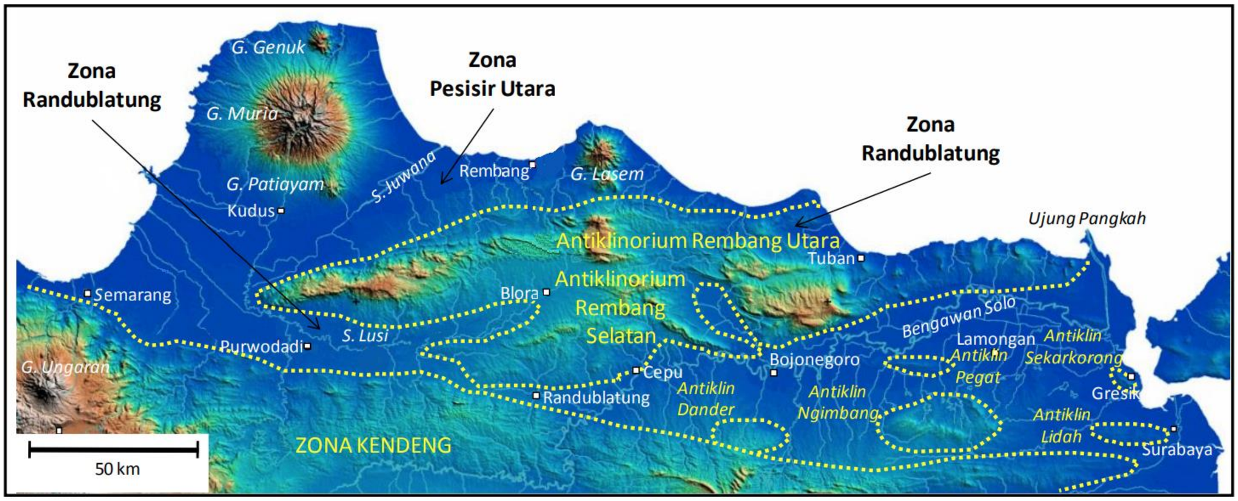

Figure 3. Profile of Randublatung Zone where the position of the Surabaya-Lamongan Groundwater Basin is located (modification from Husein, 2015; Pannekoek, 1949; van Bemmelen, 1949)

The depression form of Randublatung zone is a series of valleys that extend between the Kendeng Mountains to Rembang. The zone includes Purwodadi, Cepu, Bojonegoro, Gresik, Lamongan, Tuban, and Surabaya. Various anticline structures and isolated domes are found in the zone and occupy the Bengawan Solo River as the main river. Among them are the area of the antique structure of Dander, Pegat, Ngimbang, Sekarkorong, and Lidah (Husein, 2015). The appearance (feature) of these structures is caused by tectonic processes and sedimentation in the Randublatung Zone which has been continuous since the end of Tertiary until now. The source of sedimentation originated from the Kendeng and Rembang Mountains. In addition, there is also a drainage system in the river system (drainage system) in a zone that is divided into two, namely the Lusi River System on the west side and the Bengawan Solo River System on the east side.

Based on an analysis of regional geological maps on a scale of 1: 100,000 sheets of Bojonegoro, Mojokerto, and Surabaya-Sapulu obtained an analysis that the alluvial layer (Qal) distributed on the surface along the Surabaya-Lamongan Groundwater Basin has a thickness varying between 5 to 150 meters.This layer forms the main aquifer system in the groundwater basin system.Some groundwater irrigation network (JIAT) production wells with depths varying between 3 to 130 meters are in the aquifer layer.The utilization of JIAT is to fulfill the supply of water sources for the management of agricultural irrigation from groundwater. The role of groundwater serves as a conjunctive use.

Sampling techniques and analysis of in-situ interviews

Sampling techniques in this study use the accidental sampling method where researchers conduct semi-structured interviews to reveal the purpose of the study to farmers who happen to be encountered in the process of data collection in rice fields that are research locations, namely farmers included in CAT Surabaya-Lamongan.The data was taken through a semi-structured interview method with several farmers and other related parties who have used JIAT wells to meet the irrigation water needs of rice farms and ponds.Interview guides are prepared with attention to the purpose of research, where questions are arranged in the form of stratified questions.The purpose to be revealed through the interview is to elaborate on the pattern of the firstsecond and third planting period, stages of the fertilization process and amount of fertilizer used, type of fertilizer used by farmers, fertilization cycle, time and frequency of utilization of chemicals other than fertilizers, and time of harvest during a year.After all the data from the interview is obtained, the data processing is carried out through descriptive analysis by making a classification based on the subject's answers and compiling it into a percentage graph of the subject's answers that describe the results of the study.

3. Result and Discussion

The series of data collection from the respondents was conducted through structured interview questions.The interview guide was compiled to uncover six research objectives, namely to disclose the pattern of the planting period, reveal the stages in fertilization and the amount of fertilizer used, discover the type of fertilizer used by farmers, perceive the cycle in fertilization, to determine the time, type and frequency of use of chemicals other than fertilizers, and to cognize the harvest period and types of plant commodities each time the planting period is carried out by farmers.

The questions on the first goal about the pattern of the planting period consist of the first four questions about the first time of planting (the first growing season) for a year.The results obtained from the subject's answer to the first question of the first goal is that the planting period of rice commodities between regions varies from one region to another.For example, in one area where it is starting at the end of the year (December), while in other areas it starts at the beginning of the year (February).The duration of one planting period until the harvest lasts about three months, which is from the planting period to the harvest but does not include preparations before planting.

The second question on the first goal is related to the stages of the rice planting phase and the timing of the implementation of those stages.All respondents obtained conclusions in general about the stages of planting rice, among others, starting with the phase of plowing the soil or processing the soil to be looser.Then after that, it is left for a certain interval of time by sprinkling dolomite lime to balance the pH level of the soil.Although this is rarely done by farmers.Furthermore, the planting phase of rice seedlings is carried out.Followed by irrigation both through rain and irrigation systems (surface water and groundwater).After that enter the fertilization and administration phase of chemical drugs (controlling pests).The last is the harvest phase. All phases are carried out with a duration of about four months or a year and can be done three times the planting period process although depending back on the condition of the type/ characteristics of the land and agricultural land in the field.The third question on the first goal is related to the stages of plant treatment carried out by farmers after the planting phase. The results of the analysis obtained that after the rice is planted, the thing farmers do to their crops is to weed the grass/weeds manually.Next is fertilization. Then, spraying plants with pest-controlling chemicals and plant diseases. This process is conducted several times until the plant can be harvested.The fourth question on the first purpose relates to the frequency of fertilization carried out in one planting period. The results of the analysis were obtained that during the planting period (in one planting period) fertilization was implemented two to four times and the majority of respondents fertilized twice.The following pie diagram shows that there are three groups of fertilization durations within one planting period (Figure 4). In Figure 4, it was obtained that the majority of respondents (74%) fertilized twice within a year. While the remaining 24% fertilize three times a year and only 2% do fertilization up to four times.

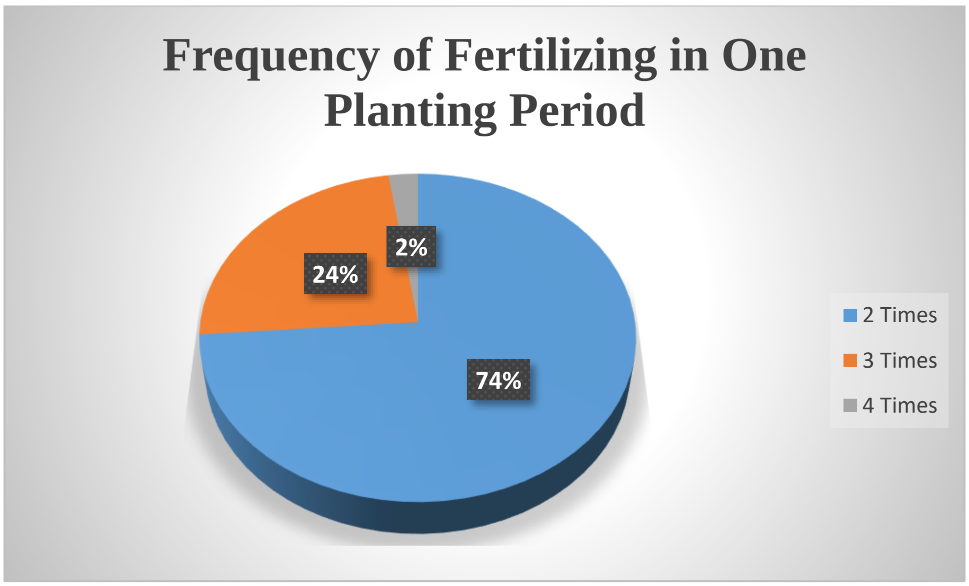

Figure 4. The pie chart on fertilizing in one planting period

The question on the second goal consists of two: the first question is to deduce the duration of time from the planting period to fertilization. The conclusion obtained is that the fertilization process in rice plants is carried out about 7 to 10 days after the planting period.Then the next fertilization is performed between 10 to 25 days after the first fertilization. The following pie diagram shows that for the first fertilization after the planting period the majority at a duration of 10 days although not absolutely (Figure 5). Furthermore, in the second fertilization after the planting period respondents, the majority were at 20 days (Figure 6) although not dominant.

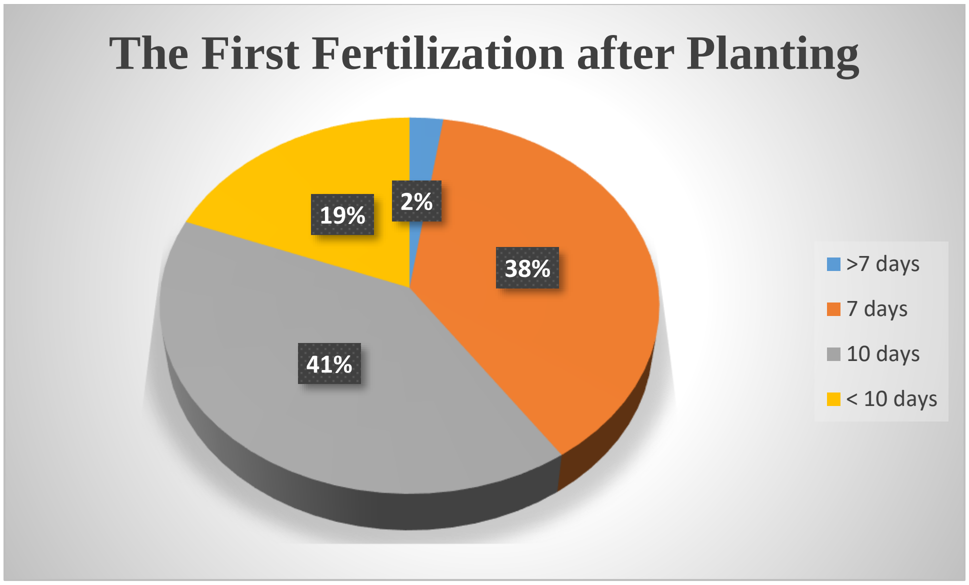

Figure 5. Pie chart first fertilizing after planting period

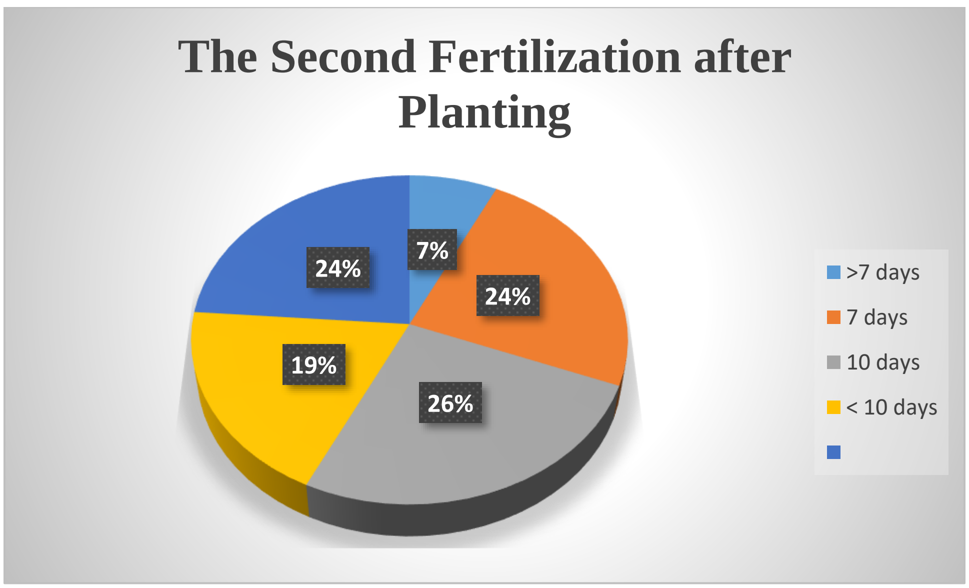

Figure 6. Pie chart second fertilizing after planting period

Figure 5 obtained the condition that the majority of respondents fertilize for the first time after the planting period with a distance of 10 days (as much as 41%); then followed by the option with a distance of 7 days (38%); the rest of the respondents chose less than 10 days (19%) and more than 7 days (2%).Furthermore, according to Figure 6, there is an almost even distribution of each respondent in choosing the option of choice related to the distance of the second fertilization time after the planting period. The majority although thin choose the distance of the second fertilization time of 20 days (26%); followed by 15 days (24%); then a distance of more than 20 days (19%); and the rest of the respondents answered more than 15 days (7%).The rest did not answer (blank-

24%). Further explanation of the first and second fertilization patterns in Figure 5 and Figure 6 is explained by Hansen et al. (1992) and Huda et al. (2012) and summarized in Figure 10.

The second question for the second purpose is related to the quantitative benchmark (dose) of fertilization. The conclusion obtained from respondents in the field is that the benchmark for the use of fertilizer by farmers varies.But in general its used 500 kg per hectare of agricultural land for one fertilization. Fertilization is carried out at least twice in one planting period. This is also reinforced by the results of in-depth interviews with farmers with the characterization of the use of fertilizer in one planting period in the rice fields of four districts and cities as table 1 below.Farmers in the four districts and cities use at least three types of fertilizer variants, namely urea, phonska, and ZA. The largest proportion of fertilizers is urea with a percentage of about 60%, while phonska and ZA each use about 20%.

Table 2 The use of fertilizer in one planting period in rice fields in 4 districts and Surabaya City

No	Regency / City	Paddys Field Area (Ha)	Types of Fertilizers			Total use of Fertilizer (Kg)
			Urea (Kg)	Phonska (Kg)	ZA (Kg)	
1.	Surabaya	1.843,83	497.834,10	165.944,70	165.944,70	829.723,50
2.	Bojonegoro	78.945,00	21.315.150.00	7.105.050,00	7.105.050,00	35.525.250,00
3.	Gresik	29.756,25	8.034.187,50	2.678.062,50	2.678.062,50	13.390.312,50
4.	Lamongan	153.316,00	41.395.320,00	13.798.440,00	13.798.440,00	68.992.200,00
5.	Tuban	56.478,00	15.249.060,00	5.083.020,00	5.083.020,00	25.415.100,00
	Total	**320.339,08**	**86.491.551,60**	**28.830.517,20**	**28.830.517,20**	**144.152.586,00**

Source: Central Statistics Agency of East Java Province, (2020); interview results to farmers (2021)

The question of the first third purpose relates to what kind of fertilizer is used by farmers. The conclusion obtained is that the majority of the types of fertilizers used by farmers are dominated by urea, phonska, ZA, SP36, TS, and petroganics. Each type of fertilizer has its characteristics. Urea fertilizer is a fertilizer (NH2-CO-NH2) with high-grade nitrogen (N) chemical components up to 46%.In general, it has white crystal grains and is easily soluble in water because it is hygroscopic (absorbing water) as the source; https://www.pusri.co.id/ina/urea-tentang-urea/. Phonska fertilizer or known as NPK fertilizer has the characteristics of a granular granule shape with an average composition of nitrogen 15%, phosphorus in phosphate form (P2O5) 15%, potassium (K2O) 15%, sulfur 9%, and zinc (Zn) 2000 ppm, as a source: https://pupuklahan.blogspot.com/2018/08/pupuk-npk-phonska-plus-panen-meningkat-karena-peran-5 -this element.html. This fertilizer is easily soluble in water and clumps (hygroscopic). ZA fertilizer (zwavelzureammoniak) has a shape like a kitchen salt in the form of grainy crystals and also has a hygroscopic capacity that absorbs water. Compared to other types of fertilizers, ZA contains fewer nitrogen levels in it, but it is safe for use in various types of plants.ZA chemical compounds are stable so that for a long time will not experience changes in physical and chemical form, as a source: https://www.solusiagro.com/apa-itu-pupuk-za/.While SP 36 fertilizer is a phosphate fertilizer with a granular form derived from phosphate rockswith a mixture of phosphoric acid-sulfuric acid and its main components containing phosphorus mono-sodium calcium phosphate (Ca (H2PO4)) as stipulated in SNI 02-3769-2005. Finally, the characteristics of carbon-grade petroganic fertilizers (C-organic) are at least 15%, C and N levels are between 15-25, the maximum moisture content is between 8-20%, at a pH between 4-9, granular so that it is easy to use, low water content so that it is efficient, as the source: https://petrokimia-gresik.com/product/petroganik.

The second question for the third purpose is to grasp whether or not there is fertilizer used other than those that have been in the free market (for example in the first question before), for example, kendang fertilizer or compost, and the amount. The conclusion was obtained that other types of fertilizers (in addition to fertilizers) that farmers have used are types of compost, kendang fertilizer, POC (sourced from livestock urine manure), and other organic fertilizer variants.The following pie diagram (Figure 7) shows that the use of fertilizers other than chemical fertilizers only reached about 29% of all respondents. This means that the majority of farmers still rely on the use of chemical fertilizers in agricultural land management. While the rest (the majority of respondents of 71%) still use chemical fertilizers predominantly.

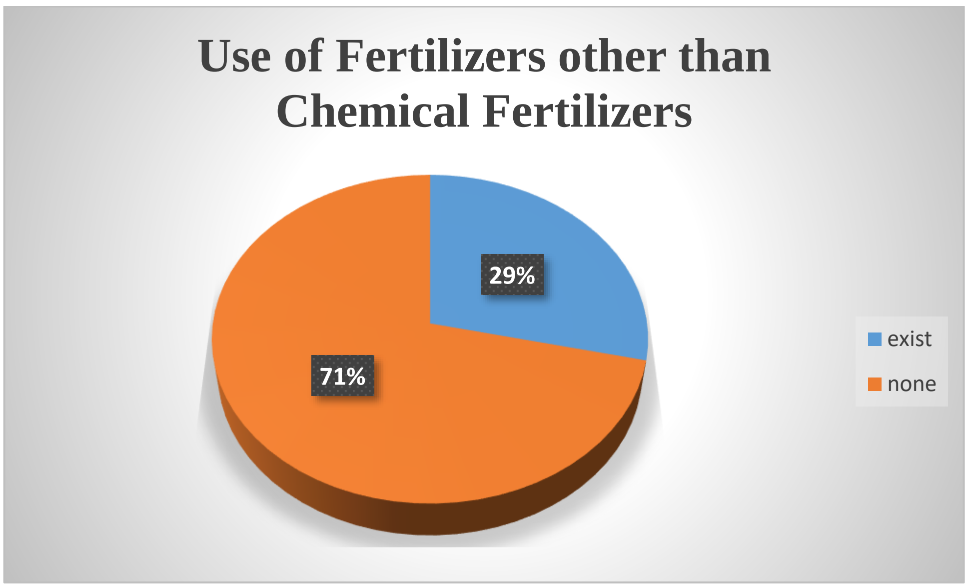

Figure 7. Pie chart related to the use of fertilizers other than chemical fertilizers (non-chemical)

The fourth goal is asked with the first two questions to find out the stages carried out in one planting period, and the length of time for each stage of fertilization. The results of the respondents obtained that the stages carried out began from weeding and pouring the soil, giving rice seedlings, irrigation (both relying on rain and irrigation systems), fertilizing, pest control with chemicals, and harvest preparation.The distance of fertilizer feeding is carried out between 10 to 25 days from the first fertilization. Furthermore, farmers provide additional chemical substances to overcome plant pests that are usually done after the second fertilization. The second question for this purpose is related to the length of time each stage of fertilization has been done by farmers. The results obtained are an average of about 25 days (first and second fertilization).

The fifth goal consists of three questions, the first is about the types of agricultural chemical drugs used by farmers (in addition to fertilizers). The results of respondents found that almost all farmers use chemical drugs to eradicate plant pests. Such substances are sown or sprayed on the plant to the ground. The drugs used include Pertaco, Amsar, Prepaton, Baykrat, Budok, Nativo, Eli, Scor, Cambrio, Villa, Amistop, Atesa, and others.The following pie diagram (Figure 8) displays that farmers absolutely use 100% of drugs/chemicals (pesticides) to control pests and plant diseases. This shows that the capacity of chemical drugs to exterminate pests/plant diseases has a better advantage compared to non-chemicals so farmers tend to rely heavily on the type of chemical preparation (fabrication).

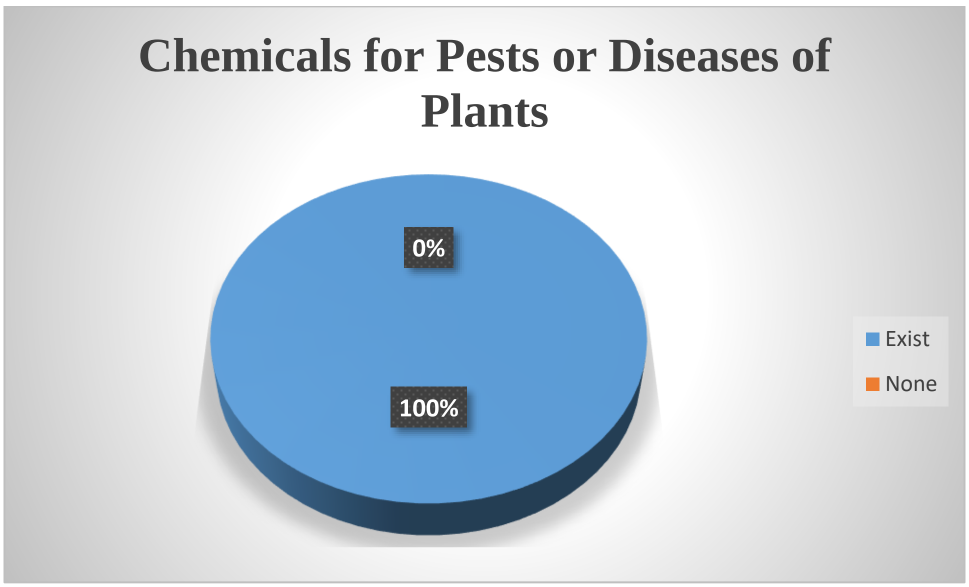

Figure 8. The pie chart shows overall farmers depend on drugs/chemicals (pesticides) to control pest disease

Chemical drugs (pesticides) have the potential to be the main source of pollutants in shallow groundwater apart from fertilizers. Rao et al (2022) asserted that the degree of groundwater pollution in the case of rural areas in Telangana, India is strongly influenced by various human activities in the form of household waste, irrigation, and so on.Rao et al also explained that the existence of various human activities can contribute to the increase of polluting sources from the main cation elements consisting of Mg^{2+}, Na^{+}, K^{+}, Ca^{2+} and the main anions are HCO_3^-, Cl^-, NO_3^-, SO_4^{2-}, F^-. This study successfully divided the source of pollutants into three kinds through the unmix model (UM).The first source (K^+) is used to measure the condition of household waste and fertilizers with potassium components. The second source (SO_4^{2-}, Mg^{2+}, NO_3^-, Na^{+}, and Ca^{2+}) specifically comes from household waste, irrigation, and chemical fertilizers with gypsum and nitrate components. The third source (F^- and HCO_3^-) that represents the process of dissolving fluoride minerals is a major component contributing to chemical levels in groundwater.All components of the cation and anion are contained in chemical manufacturing fertilizers and drugs /pesticides used by farmers at the study site.

The second question on the fifth purpose given to the subject is about the function of chemicals other than fertilizers used by farmers if any. The results of the respondents obtained that the provision of these drugs was carried out when plants were attacked by pests and diseases in the form of fungi, viruses, bacteria to animals such as leafhoppers, and so on.While the third question is about the time of treatment done for rice plants. The results of the respondents concluded that the administration of these chemical drugs is carried out when plants are attacked by pests and diseases.The frequency of giving is generally done three times in one planting period. The frequency is done to provide a protective effect of plants against potential pests and diseases. Conditions for the use of fertilizers and pest exterminator drugs and diseases are intensive enough that they will have the potential to produce a source of pollution for the surrounding environment.Some previous studies in South Korea have found that the impact of excessive fertilizers and pest/disease eradication drugs on shallow groundwater quality becomes degraded. The degradation process is mainly due to the residual level of fertilizers and pesticides with components ofNO_3^- and SO_4^{2-}which dominate the groundwater content around the agricultural area (Min et al., 2003; Chae et al., 2004; Choi et al., 2007; Kim et al., 2008; Choi et al., 2011, 2016; Kim et al., 2014, 2015).The above has characteristic similarities with conditions at the study site with the dominant composition of fertilizers and pesticides derived from the affiliates of NO_3^- and SO_4^{2-}components.

The sixth goal is expressed with one question on the subject of how many harvests in one year; Answers can be grouped into three categories based on answers obtained from farmers, namely twice the harvest, three times the harvest, and blank or empty.The empty answer is that some farmers refuse to give a clear answer to this question for reasons that cannot be explained by researchers. The question on the sixth goal also reveals the type of plant grown in one year.The conclusion of the respondents was obtained that in one year almost all areas can be done three times the planting period, the rest only twice. Then for three times the planting period, not all can be planted rice (three times) so most are interspersed withpalawija crops such as corn, soybeans, green beans, peanuts, vegetables, and tobacco in some cases.This is the following pie diagram which shows the characteristic distribution of the number of harvests in one year (Figure 9). This diagram confirms and exhibits that the majority of respondents (81%) harvest rice three times a year while the rest (14%) harvest rice twice, and the rest abstain.Hansen et al. (1992) and Huda et al. (2012) explained that the mechanism of regulating water sources (surface and groundwater) in rice agricultural irrigation systems follows the stages of flooding, the use of small and large furrows, the use of groundwater as a subjunctive use of rice plants, watering (sprinkle system), and the use of leaking systems (Trinkle systems). Distribution of groundwater continuously or intermittently (Figure 10).The figure also describes the general position and duration of the use of fertilizers and pesticides as exterminators of pests and diseases.

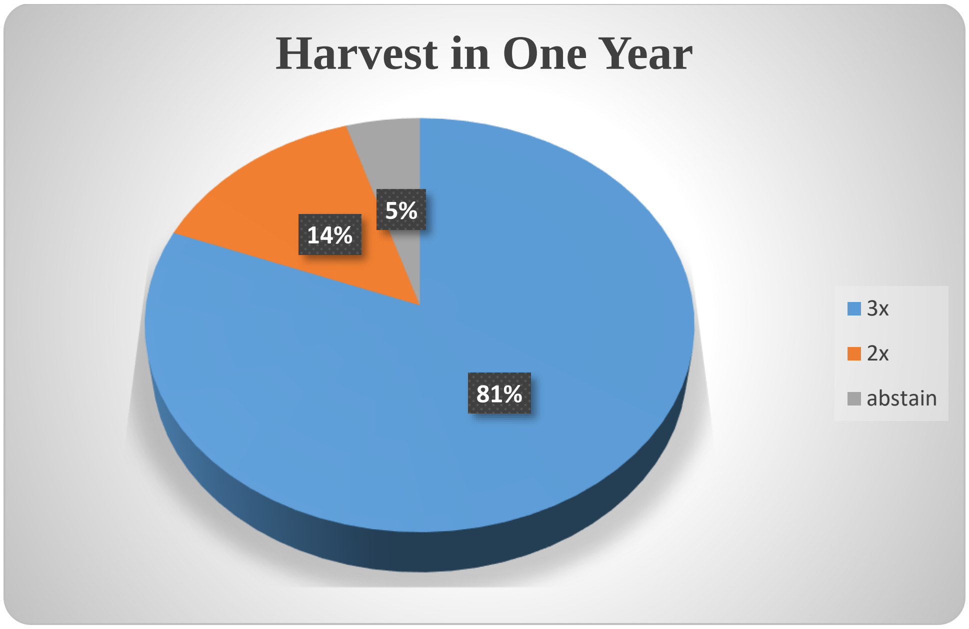

Figure 9. Pie chart characteristics of the number of harvest periods in a year

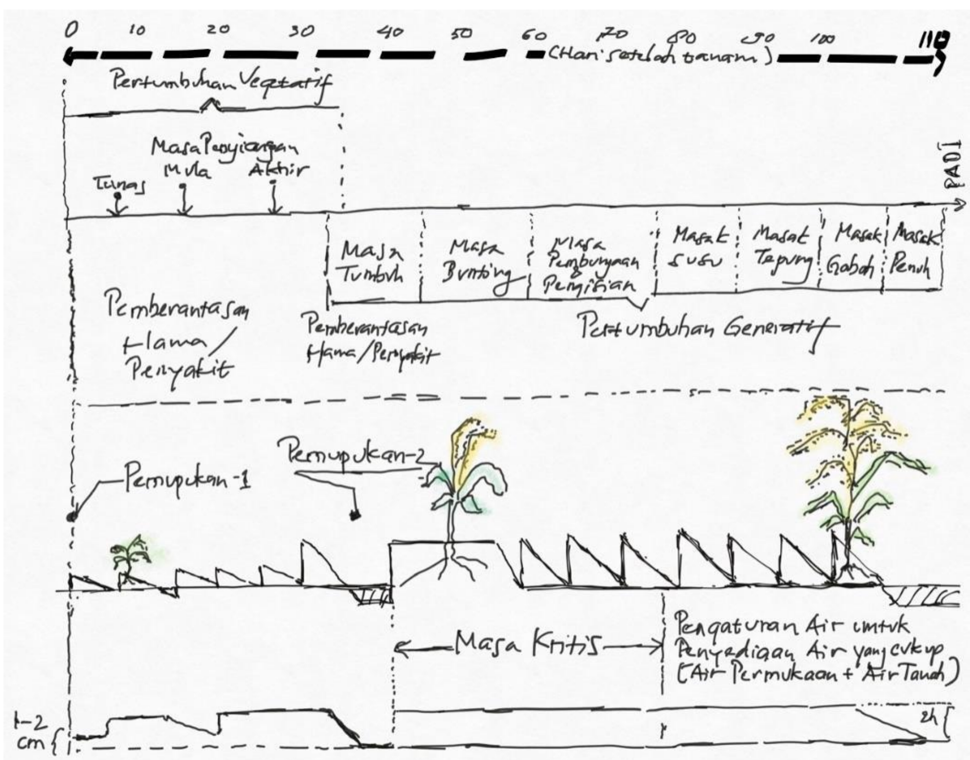

Figure 10. Scheme of distribution and distribution of fertilizers, pesticides, and water in rice irrigation systems (modifications of Hansen et al., 1992; Huda et al., 2012)

4. Conclusion

Based on all the data and reviews in the previous section, it can be concluded that:

a. The results of the data analysis uncovered a tendency to increase the intensity and volume of the use of fertilizers and chemical drugs in the early growing season.
b. The planting period of rice commodities reaches an average of between two to three times a year so it demands the availability of water and fertilizers and chemical drugs (pesticides) which are also increasing.
c. The use of fertilizers or chemical fertilizers dominates the frequency of farmers so the potential opportunities for pollution to the surrounding environment include shallow groundwater aquifers. So is the intensive use of pesticides. This indicates the potential for shallow groundwater pollution in the Surabaya-Lamongan Groundwater Basin area.
d. The results of this study are the starting point for research related to groundwater contaminants that are suspected to also be caused by human activities, especially in the Surabaya-Lamongan Groundwater Basin area.

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