Assessing the irrigation system distribution to the cropping index and rice land potency in North Tapanuli Regency

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Abstract. The irrigation system is one of the main supporting factors to increase the production of an agricultural commodity, especially for rice. Recently, the significant contribution from the irrigation system gives small value because of some issues such as climate change, land use change, and the infrastructure damage from the irrigation infrastructure system itself. Indeed, it is affecting the total rice production. This study has objectives to map the distribution of irrigation canal system and to observe the correlation of irrigation canal distribution to the cropping index, total irrigated-area, total harvested area, and the total rice production in North Tapanuli Regency. The Geographical Information System (GIS) was applied for the mapping of the irrigation canal system distribution, and the SPSS through Pearson Correlation was implemented as well to analyze the correlation of the irrigation system in rice cultivation. The results show that the distribution of irrigation canal system has no correlation with the total irrigated area and the other parameters. Besides, it was found that the highest of the total irrigated area is located in Siborong-borong, Pangaribuan and Pagaran Districts by covered 2,561 ha, 2,254 ha and 1,711 ha, respectively. Then, it was observed that the total irrigated area has significant correlation with the total harvested area, total production and productivity. In addition the cropping index has positively correlation with the total rice production. Based on the results, it needs to increase the irrigated-coverage area on the districts level, to enhance the future rice production sustainability.

1. Introduction
Mostly agricultural commodity is strongly requiring suitable agricultural environment to support their growth; and supporting water availability is the main part of it. By water availability, the biological, chemical and physical land fertility will be existing and give significant output to the crop yield. Rice is one of the agricultural crops that highly need water to produce well. There are four phases of rice growth that water must be available for giving the satisfying production, at soil tillage phase, planting phase, applying fertilizer phase and grain filling phase [1].

Nowadays, the water existing for watering the crop is one of crucial problems as well. The issue of climate change may occur drought in some area [2]. Drought is a natural hazard that agricultural sector is the most affected. This particular hazard may affect the failure of production, increase the production cost and decrease farmer’s income. Fortunately, there are some practices that farmers can adapt to face this problem such as sowing drought-tolerant variety, plant other crops, change crop pattern, water harvesting, and build dam or irrigation system. Rice, by the specific variety, is also can be planted on the unirrigated land, unluckily its production is less than on the irrigated land [3].

One of efforts to boost agricultural development is by building irrigation system. There are some ways to increase the capability of irrigation system, such as by making the new irrigation infrastructure,
by fixing the damaged irrigation canal system, and by taking care of the existing (old) irrigation canal system as well [4]. Building and taking care the infrastructure of irrigation system is one of strategies to solve the water scarcity, especially in the dry season. Furthermore, the cropping index will increase through the availability of irrigation system.

North Tapanuli Regency is one of regencies in North Sumatera Province which is located on the highland. In terms of rice production, it gives a significant contribution by 158,031 t in 2019 or about 6% of total provincial production [5]. This regency has higher rice productivity compare with the provincial level by 5.9 t/ha and 5.28 t/ha, respectively. However, this achievement is still possible to be improved by observing the carrying capacity of rice land. Some issues were reported related to the irrigation system in this regency specifically [6, 7], such as the low quality of irrigation infrastructure and irrigated-water as well, the problem on the distribution of irrigated-water to farmers’ rice land, and the low level of farmers’ awareness to manage the infrastructure and irrigated-water of irrigation system. Thus, it is very important to conduct this study with the two main objectives, namely: to map the distribution of irrigation canal system and to investigate the influence of irrigation canal system on the cropping index and rice land potency. Some outputs from this study will be necessary for the local government to generate the specific strategies action, which is important for the farmers and for agricultural development in North Tapanuli specifically.

2. Methodology

This study was conducted in North Tapanuli Regency, where located at 98° 05’ – 99° – 16’ E and 1° 20’ – 2° 41’ N astronomically. It has several of elevation that range from 150 to 1,700 m above sea level. As geographical site, this regency is bounded by five regencies where at northern border with Toba Samosir Regency, at eastern border with Labuhan Batu Regency, and at southern and western border with South Tapanuli and Humbang Hasundutan Regency, respectively. North Tapanuli Regency has about 3,793.71 km² of total area. It is divided by 15 districts and Garoga District and Muara District is the highest and the lowest of total area among of the other districts by 567.58 km² (14.96% of total area) and 79.75 km² (2.10% of total area) [8].

Figure 1. The location of study area.

The methodology for this study is the survey method, by collecting primary and secondary data. The primary data was collected using in-depth interviews of key informant related to the raw data of total
rice land area and total number of the existing irrigation system. Meanwhile, the secondary data were gathered from the Statistical Institution of North Tapanuli Regency and from Indonesian Agency for Agricultural Resources and Development (IAARD), such as: total of rice production, productivity, total harvested area, administrative boundary, and the river system. In terms of the cropping index, it can be determined by dividing the total of harvested area with the raw data of total rice land area. Besides, the Geographical Information System (GIS) application was applied to make further a map of the distribution of irrigation canal system in North Tapanuli Regency by overlaying the shapefile of administrative district boundary, river system, and irrigation canal points. In the end, the Pearson Correlation was implemented to determine the correlation or the influence of the irrigation system with the rice production, productivity and the cropping index level in North Tapanuly Regency. Through the output, some strategies will be informed to the farmers and local government.

3. Results and discussion

3.1. Identification of irrigation system distribution

Based on the result, it found that North Tapanuli Regency has 16,820 ha and 1,983 ha for the total of irrigated rice land and unirrigated rice land, respectively. It was spread in all districts by different proportion. Siborong-borong District, Pangaribuan and Pagaran District have the highest proportion of irrigated rice land by 15.23%, 13.40% and 10.17% from total irrigated rice land, respectively. While, Sipoholon District, Siatas Barita and Parmonangan District have the lowest of total irrigated rice land by 1.78%, 2.87% and 3.57%, respectively. In term of the total number of irrigation infrastructure, Siborong-borong and Pagaran Districts has the highest by 19 units and 10 units. In contrast, Pangaribuan, Garoga and Sipahutar Districts has the lowest by 1 unit for each district (as presented in table 1).

| District       | Number of Irrigation Infrastructures (unit) | Total Rice land Area (ha) | Irrigated | Unirrigated | Total |
|----------------|--------------------------------------------|---------------------------|-----------|-------------|-------|
| Parmonangan    | 2                                          | 600                       | 285       | 885         |       |
| Adian Koting   | 2                                          | 802                       | 0         | 802         |       |
| Sipoholon      | 8                                          | 300                       | 800       | 1,100       |       |
| Tarutung       | 9                                          | 779                       | 0         | 779         |       |
| Siatas Barita  | 4                                          | 483                       | 0         | 483         |       |
| Pahae Julu     | 6                                          | 1,233                     | 0         | 1,233       |       |
| Pahae Jae      | 7                                          | 1,316                     | 0         | 1,316       |       |
| Purba Tua      | 2                                          | 720                       | 460       | 1,180       |       |
| Simangumban    | 4                                          | 706                       | 34        | 740         |       |
| Pangaribuan    | 1                                          | 2,254                     | 0         | 2,254       |       |
| Garoga         | 1                                          | 859                       | 0         | 859         |       |
| Sipahutar      | 1                                          | 1,572                     | 0         | 1,572       |       |
| Siborong-borong| 19                                         | 2,561                     | 140       | 2,701       |       |
| Pagaran        | 10                                         | 1,711                     | 24        | 1,735       |       |
| Muara          | 6                                          | 924                       | 240       | 1,164       |       |
| **Total**      | **82**                                     | **16,820**                | **1,983** | **18,803**  |       |

The ArcGIS application is one of the practical tools that very useful to map an area for the specific purpose. By using this tool for this study, will simply flying the complicated problem, particularly in spatial form. Rather than look at the number, it will be easier for the reader when monitoring the proportion of irrigation canal system distribution at district level through a map (as shown in figure 2).
3.2. Potency of rice cultivation in North Tapanuli Regency

The potency of rice cultivation for this study was investigated by total harvested area, cropping index, production and productivity parameters. This potency can be observed from table 2 that describes all parameters at district level. For the particular total harvested area of rice, Pahae Jae and Purba Tua Districts give the highest proportion by 14.68% and 11.48%, respectively; while Siatas Barita and Adian Koting Districts give the lowest by 2.35% and 3.29%, respectively.

Table 2. Potency of rice land in North Tapanuli Regency.

| District       | Harvested Area (ha) | Raw Rice land (ha) | Cropping Index | Production (t) | Productivity (t/ha) |
|----------------|---------------------|--------------------|----------------|----------------|---------------------|
| Parmonangan    | 1,097.2             | 885                | 1.24           | 6,506          | 5.93                |
| Adian Koting   | 881.8               | 802                | 1.10           | 5,225          | 5.92                |
| Sipoholon      | 1,209.5             | 1,100              | 1.10           | 7,172          | 5.93                |
| Tarutung       | 911.5               | 779                | 1.17           | 5,407          | 5.93                |
| Siatas Barita  | 630.1               | 483                | 1.30           | 3,730          | 5.92                |
| Pahae Julu     | 1,432.6             | 1,233              | 1.16           | 8,495          | 5.93                |
| Pahae Jae      | 3,932.1             | 1,316              | 2.99           | 23,231         | 5.9                 |
| Purba Tua      | 3,073.2             | 1,180              | 2.60           | 18,156         | 5.9                 |
| Simangumban    | 1,627.4             | 740                | 2.20           | 9,614          | 5.9                 |
| Pangaribuan    | 2,478.4             | 2,254              | 1.10           | 14,686         | 5.92                |
| Garoga         | 944.1               | 859                | 1.10           | 5,534          | 5.86                |
| Sipahutar      | 1,728.5             | 1,572              | 1.10           | 10,132         | 5.86                |
| Siborong-borong| 2,969.9             | 2,701              | 1.10           | 17,409         | 5.86                |
| Pagaran        | 2,336.6             | 1,735              | 1.35           | 13,697         | 5.86                |
| Muara          | 1,524.2             | 1,164              | 1.31           | 9,037          | 5.92                |
| **Total**      | **26,777.1**        | **18,803**         | **1.42**       | **158,031**    | **5.90**            |
For the cropping index at district level, it was measured by divided the total harvested area to total raw rice land area. The cropping index itself refers to the times of sequential crop planting in the same arable land in one year [9]. Thus, it can be observed that Pahae Jae District has almost three (2.99) for its cropping index, which means that there will be three times in a year that rice may be planted in Pahae Jae District. In terms of total rice production, again Pahae Jae District significantly contributes to the total rice production by 23,231 t in 2019 and followed by Purba Tua and Siborong-borong Districts by 18,156 t and 17,409 t, respectively. For the last parameter, all districts have a relatively equal for the rice productivity which is ranges from 5.86 to 5.93 t/ha.

3.3. The influence of irrigation system to the potency of rice land

For investigating the influence of irrigation system to the potency of Rice land in North Tapanuli Regency, this study applied the Pearson Correlation analysis. This analysis determined whether and how the strongly of the two investigating-variables have correlation or not. The correlation itself may has positive or negative value. The correlation is positive when both the variables increased together, while if negative when one value decreased as the other increased.

Table 3. The correlation of irrigation system to the potency of rice land in North Tapanuli Regency.

|                | No-Irrig | Tot-Irrig | Tot-Unirrig | Tot-RawRice | Tot-Harvest | CropIndx | Tot-Prod | Prov |
|----------------|----------|-----------|-------------|-------------|-------------|----------|----------|------|
| No-Irrig       | 1        |           |             |             |             |          |          |      |
| Tot-Irrig      | .432     |          |             |             |             |          |          |      |
|                | .107     |          |             |             |             |          |          |      |
| Tot-Unirrig    | .098     | .395     | 1           |             |             |          |          |      |
|                | .729     | .145     |             |             |             |          |          |      |
| Tot-RawRice    | .508     | .935**   | .044        | 1           |             |          |          |      |
|                | .053     | .000     | .875        |             |             |          |          |      |
| Tot-Harvest    | .319     | .582*    | .015        | .639*       | 1           |          |          |      |
|                | .246     | .023     | .958        | .010        |             |          |          |      |
| CropIndx       | -.077    | -.143    | .054        | -.135       | .662**      | 1        |          |      |
|                | .786     | .610     | .848        | .631        | .007        |          |          |      |
| Tot-Prod       | .315     | .578*    | .017        | .635*       | 1.00**      | .665**   | 1        |      |
|                | .253     | .024     | .952        | .011        | .000        | .007     |          |      |
| Prov           | -.232    | -.520*   | .275        | -.460       | -.363       | -.033    | -.355    | 1    |
|                | .406     | .047     | .322        | .084        | .184        | .907     | .194     |      |

** = Correlation is significant at the 0.01 level (2-tailed)
* = Correlation is significant at the 0.05 level (2-tailed)

Note: No-Irrig (Number of Irrigation System); Tot-Irrig (Total of Irrigated Rice land); Tot-Unirrig (Total of Unirrigated Rice land); Tot-RawRice (Total of Raw Rice land); Tot-Harvest (Total Harvested Area); CropIndx (Number of Cropping Index); Tot-Prod (Total Production); Prov (Productivity).

Based on the correlation analysis result which is presented in table 3, it shows that total number of irrigation canal or infrastructure system has no correlation with all potential parameters. It could be happened because the parameter only described about the total number of irrigation canal. It can be observed that Pangaribuan and Sipahutar Districts have only one unit of irrigation canal but covered 2,254 ha and 1,572 ha of total irrigated-rice land area, respectively; while Siborong-borong and Pagaran Districts have ten units of irrigation canals but covered only 2,561 ha and 1,711 ha only of total irrigated-rice land area. It can be concluded that there is no significant difference between the small and high number of irrigation canal system in term of total irrigated-rice land area.

For the total of irrigated-rice land area, it has significant correlation with the total of raw rice land, total harvesting area, total rice production and productivity. In this case, local government together with farmers collaborate to develop rice land area. It can be observed that by increasing the total raw rice land area, the total of irrigated-rice land, total harvesting, and total production increased as well. Unluckily, for the particular productivity has negative value, means increased the total of irrigated-rice
land will declining the rice productivity. There are three possible explanation about this case. First, it might be affected by the broken irrigation infrastructure [6, 7], then cannot give the maximal contribution to rice productivity. Secondly, the declining of the irrigation water volume due to climate change issue from primary and secondary irrigation to the tertiary irrigation. The last, it is estimated by the small gap of productivity level at district level which is ranges from 5.86 – 5.93 t/ha. Thus, regarding to this output, it is important to continue this study to investigate the others factors influencing the rice productivity, which is might be about the level of soil fertility, or the dosage level of fertilizer implementing by farmers, or the skill/ capability level of farmers, etc.

Undoubtedly, the increased of total raw rice land area is significantly increase the total harvesting area and total production as presented in table 3. In terms of total harvesting area, it has positive correlation as well to the cropping index and the total rice production. Then, the increase of cropping index of rice indeed significantly increases the total rice production.

Another information getting from this study is about the potency of rice production and productivity in North Tapanuli Regency is still possible to be enhanced. There are so many opportunities from land resource on this regency, such as the wide total rice land and supporting of river system pass on some districts. This study also suggests to do continuing research focus on the inventory the quality of irrigation infrastructure in North Tapanuli Regency and investigate its impact on rice productivity. Thus, the expecting output, there will be additional of irrigation infrastructure for this regency, so will increase the rice production in the future.

4. Conclusion
There are 18,803 ha of total rice land area in North Tapanuli Regency, where about 89.5% of the area is classified as irrigated-rice land. The District of Siborong-borong, Pangaribuan and Pagaran have the highest proportion of irrigated-rice land by 15.23%, 13.40% and 10.17%, respectively. This study found that the total of irrigated-rice land shared significant correlation to the total production, total harvesting area and the productivity of rice as well, while to the cropping index is insignificant. Then, the total of harvesting area has positive correlation with to the cropping index and the total rice production. Some strategic actions to enhance sustainable rice production in North Tapanuli Regency are by building the infrastructure of irrigation system, and followed by the actions of water harvesting, changing the crop pattern, sowing tolerant-drought variety, and increasing cropping index.

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