Chili Cultivation on Tin Mined Land at Bangka Island: Prospects and Constraints

I G M Subiksa\textsuperscript{1}, I W Suastika\textsuperscript{1} and Sutono\textsuperscript{1}

\textsuperscript{1}Indonesian Soil Research Institute

Abstract. Chili (Capsicum \textit{sp.}) is one of most valuable crop in some part of Indonesia due to high price and profitability compared to another crop. However, growing chili needs high capital and special expertise due its growth requirements. All chili cultivar needs good drainage land and good soil nutrients status for their optimum growth. Meanwhile, tin mined land is very degraded land and the tailing dominated by quartz sand. Poor soil physical properties and poor nutrient status cause this land unsuitable for most crops including chili. However, high demand and high price, promises profitable chili cultivation on such land. Advanced technologies in fertilizer and water management have been assessed at Bukit Kijang Village, Bangka Island and showed very promising results for expansion. Amending soil with mixture of manure and biochar increased water holding capacity and cation exchange capacity and hence, increased yield. Although attained yield of chili was 5.7 t ha\textsuperscript{-1}, which is about 23.7\% from the average of agronomic potential yield, the net profit ranged from IDR 51.8 to 92.9 million per year after taking into account the investment for fertigation installation. The main constraints identified included low water holding capacity due to sandy texture. However, this constraints could be solved by drip irrigation technique and fertigation system. Pest and diseases were another contraints that also contributed significantly to decreased chili yield.

1. Introduction
Chilli (Capsicum \textit{sp.}) is one of common crop which cultivated throughout Indonesia, therefore it is determined as one of strategic commodity. Chili is not only used as a spice and adds flavor to cuisine, but also has health benefits. Study results showed that consuming chili can reduce the risk of stroke and maintain heart health. Besides that chili contains a lot of vitamin C, vitamin A, betacarotene and minerals needed to keep the body healthy.

Chili is also consider as valuable crop due to high price and profitability. \cite{1} stated that chili price substantially increased ahead of special moment. Chili price at local market in Bangka island can reach Rp. 100,000 per kg. Therefore many farmer cultivated chili as their family’s income. There is three cultivar which is most common cultivated in Indonesia namely common red chili (Capsicum annum), curly red chili (Capsicum annum) and bird chili or cayenne (Capsicum frutescens). Kind of chili cultivated is depend on local people preference. People in Java are prefer common red chili, meanwhile people outside of Java prefer curly red chili or cayenne pepper.

Chili can grow well in wide range of altitude from 0 – 1400 m asl, where it is depend on chili cultivar. Bird chili or cayenne grow better in lowland (< 500 masl), curly red chili in medium plateau and common red chili grow better in high plateau. However, in general chili requires fertile soil and good drainage soil for it’s optimum growth. Soil fertility and good management practices are determining factor to the success in chili farming. Land constraints must be overcome by applying...
technology to reduce the impact of land constraints. The question then is whether chili can cultivated on tin mined land, that classified as degraded land?

Tin mined land is very degraded land as impact of open tin mining operation, then actually unsuitable for most of agricultural crops. Most of mined land consist of sandy tailing which dominated by quartz sand [1]. As a result, tin mined land have poor soil properties both of physical, chemical and biological properties. [16] showed that sand fraction of tin mined land at Bukit kijang village is about 84% that causes soil has low water holding capacity. Sand content > 85% is also reported by Santi [6,15] in several other places. The soil with the dominant sand fraction causes the soil unable to keep soil moisture, easily dries and increasing soil temperature very high at noon. Rain water as a natural source of water will leach out quickly through infiltration and evaporation processes. As a result the plants will experience drought stress and even in the worst condition it will be dead. Reduced land cover also potential to change local microclimate conditions. High local air temperature causes the plants grown in extreme environmental stress. [2] suggested that maximum land surface temperature in sandy tailings can reach 48.8°C. [17] also reported surface temperatures of sandy tailings ranged from 40.0-50.0°C.

Sand texture is also causes low nutrient holding capacity. [16] reported that cations exchange capacity (CEC) of soil at the research site is 2.19 cmol.kg$^{-1}$. The similar condition also reported that CEC of sandy tailings is only about 4.35 cmol.kg$^{-1}$ [15] and 2.27 cmol.kg$^{-1}$ [6] at the other site of Bangka. Furthermore, [16] showed that nutrient status of sandy soil is very low. Total N recorded only 0.03% and total C-organic only 0.21%. Meanwhile P$_{2}$O$_{5}$ and K$_{2}$O is only 14 mg.100 g$^{-1}$ and 3 mg.100 g$^{-1}$ respectively. The macro nutrient content such as N, P, and K in sandy tailing and humic tailing are in range low to very low. N-total content ranged from 0.03-0.17%, P-Bray 4.20 -10.65 μg g$^{-1}$. K-exch 0.00 – 0.32 cmol kg$^{-1}$. [14] concluded that very low nutrient content and bases cations were due to soil texture dominated by sand fractions. The same condition was also reported by [3] in Malaysia Peninsular and by [17] in Thailand.

Although actually tin mined land is consider to be unsuitable for plants, tin mined land can still be utilized through extra efforts to improve land conditions. The main efforts is improvement the ability of soil to hold water and nutrients and provide nutrients needed by plants. Biochar can improve the physical properties both of acid non-acid mineral soils, namely increasing total pore space (TPS), fast drainage pores (FDP) and available water [8]. Various studies have shown that biochar is effective in retention of water [11,12,13], [8,10] showed that biochar as soil ameliorant can also increase pH, nutrients availability and CEC after 2 planting seasons. [6] showed that biochar, both husks and Acasia mangium, when mixed with manure, had a better effect compared to just manure.

This paper will be assess about the prospect and constraints of chili cultivation on tin mined land based on experiences and research result on reclamation and rehabilitation of tin mined land that held during 2016 – 2019 at Bukit Kijang Village, Namang, Central Bangka District.

2. Prospect of Chili Cultivation

2.1. Land availability

Tin mined land widely spread out in Bangka Belitung provinces (Babel), the largest tin producer in Indonesia. In Bangka Island itself, 321,577 ha in the mainland is belong to Tin Mine Concession of PT. Timah [4]. Most of the mined land is left abandoned even though the company is obliged to carry out land rehabilitation. Local people can ask permission to use the land to cultivate both of food crops or vegetable crops. However, farmers have to make extra efforts because their land conditions are infertile.

Tin mined land has different characteristics compared to land that has not been mined, where there has been a decline in land quality (Table 1). Significant changes that have occurred are the texture of the soil turned into sand. Soil organic matter and nutrient content also substantially declined. Sandy texture soil will experiences drought quickly because the soil is unable to hold water after rain. To avoid drought, farmer must make a well as a water source or use a pond around the farmland to water
the plants when there is no rain. There are many excavated pond named kolong around the farmland that can be used as water sources for watering the crops. Farmers must also add ameliorant to increase water and nutrients holding capacity.

Table 1. Chemical characteristics of composite soil sample taken from tin mined land and undisturb land at Bukit Kijang village Bangka.

| No. | Parameters                          | Value       |
|-----|-------------------------------------|-------------|
|     |                                     | Tin Mined Soil | Undisturb Soil |
| 1.  | Texture                             |             |
|     | Sand                                | 84          | 65            |
|     | Silt                                | 13          | 9             |
|     | Clay                                | 3           | 26            |
| 2.  | pH                                  |             |
|     | H2O                                 | 5.7         | 4.9           |
|     | KCl                                 | 4.9         | 4.5           |
|     | Organic matter                      |             |
|     | C-organic (%)                       | 0.21        | 1.89          |
|     | N (%)                               | 0.03        | 0.15          |
|     | C/N ratio                           | 7           | 12.6          |
|     | Extractable HCl 25%                 |             |
|     | P2O5 (mg 100 g⁻¹)                   | 14          | 60            |
|     | K2O (mg 100 g⁻¹)                    | 3           | 70            |
| 3.  | P2O5 (Bray-1)                       | 21          | 28            |
|     | Exchangeable cations                |             |
|     | Ca (cmol kg⁻¹)                      | 0.29        | 0.89          |
|     | Mg (cmol kg⁻¹)                      | 0.12        | 0.44          |
|     | K (cmol kg⁻¹)                       | 0.05        | 0.25          |
|     | Na (cmol kg⁻¹)                      | 0.02        | 0.10          |
|     | Total (cmol kg⁻¹)                   | 0.48        | 1.68          |
| 8.  | CEC (cmol kg⁻¹)                     | 1.38        | 7.30          |
| 9.  | Al, KCl 1N (cmol kg⁻¹)              | 0           | 1.45          |
| 10. | H, KCl 1N (cmol kg⁻¹)               | 0.10        | 0.15          |
| 11. | Base saturation (%)                 | 35          | 23            |
| 12. | Al saturation (%)                   | 0           | 20            |

2.2. Chilli Supply and Demand

Characteristics of supply and demand for chili commodities in the Bangka region are also indicative of the prospect of tin mined land utilization for chili cultivation. Searching results in the local market for chilli commodities in Bangka, showed that most of the chillies were imported from outside the area so that the price is expensive. The national average chili price in 2018 reached 44 thousand rupiah. Even at certain moments the price can surge very high. In April to May 2019, the average of chilli price at National level about Rp. 55,000/kg (Figure 1), meanwhile in the local market at Bangka has reached Rp. 90,000/kg. This condition is a big opportunity for local farmers to grow chili to meet the needs of the local market. The cultivation of chili around Bangka becomes very competitive because competitors are very limited so farmers can get high profits. Searching result also revealed that local
people tend to prefer cayenne peppers compared to red chilies, so farmers can cultivate cayenne pepper to get higher profits.

2.3. Chilli Farming Technologies

Proven technologies to support good agriculture practices in chilli farming have been released by Ministry of Agriculture. Those technologies consist of seeds, land preparation, soil amendment, fertilization, irrigation, pest and diseases control, harvest and post harvest management. There are 37 high yielding varieties of cayenne available that can choose by farmer depend on local market preference. Good seed selection is the initial step that really determines plant growth and yield.

![Figure 1. The average of chili price in Indonesia during April to May 2019](image)

Farming technologies on tin mined land is focused on soil amendment, fertilization and irrigation which are different with chilli cultivation on common farmland. This is because of the problems faced are very specific namely the soil is unable to retain moisture, soil is unable to hold nutrients, very poor nutrient content and nutrient as subject to leaching. Manure and mixture of manure and biochar application on tin mined land increased soil moisture content at certain soil tension (Table 2). This is indicate that water holding capacity of soil increased with both of manure and mixture manure+biochar treatment. The treatment of organic matter in the form of manure and biochar also increases CEC and nutrient availability for plants (Table 3). Similar result also stated by Nurida et al. (2014) and Gerard et al. (2018) where biochar as soil ameliorant can also increase pH, nutrients availability and CEC after 2 planting seasons. [6] also showed that biochar, both husks and Accasia mangium, when mixed with manure, had a better effect compared to just manure. Organic matter should be apply continuously because organic matter will decompose very fast due to high temperature.

| Treatment                     | Soil moisture content (%) |
|-------------------------------|---------------------------|
|                               | pF-1     | pF-2     | pF-2.54  | pF 4.2 |
| Before treatment              | 37.2     | 16.7     | 12       | 2.8    |
| Manure 24 ton ha\(^1\)        | 39.6     | 19.6     | 13.4     | 5.3    |
| Manure+biochar 24 ton ha\(^1\)| 40.8     | 18.7     | 14.2     | 4.7    |

Table 2. Effect of organic matter on soil moisture content at certain soil tension
Table 3. Chemical characteristic of soil mined land before and after organic matter treatment

| Treatment                  | pH   | Org-C (%) | N (%) | CEC (cmol kg\(^{-1}\)) | P\(_2\)O\(_5\) (mg 100 g\(^{-1}\)) | K\(_2\)O (mg 100 g\(^{-1}\)) |
|----------------------------|------|-----------|-------|-------------------------|----------------------------------|-----------------------------|
| Before treatment           | 5.7  | 0.21      | 0.03  | 1.38                    | 14.0                             | 3.0                         |
| Manure 24 ton ha\(^{-1}\) | 5.87 | 0.68      | 0.07  | 2.82                    | 62.6                             | 4.7                         |
| Manure+biochar 24 ton ha\(^{-1}\) | 6.10 | 0.90      | 0.08  | 4.30                    | 70.5                             | 6.1                         |

Fertilizer application was carried out through fertigation system using a special AB-mix fertilizer formula. The AB-mix fertilizer, both of commercial and AARD formula, have significantly effect and consistent to the number of harvested chili fruits and total attained yield compare to conventional NPK fertilization. [5] also stated that the fertigation system can increase growth and yield of fresh chili. This is because of the AB-mix fertilizer has complete nutrient content both macro and micro nutrients, while conventional NPK content is only macro nutrients N, P and K. As mention before, tin mined land has low macro and micro nutrient status, so that all nutrient needed for optimum growth should be provided through fertilization. The micro nutrient such as Cu, Zn and B play an important role in generative growth which includes the formation of flowers and fruits.

![Figure 2. The average of actual attained yield by type of fertilizers from 16 consecutive harvest](image)

By applying chilli cultivation technology that is suitable for local land conditions, the productivity of cayenne pepper on the tin mined land can reach 5-8 tons per hectare. The productivity achieved is indeed still relatively low compared to the potential yield of cayenne plants around 15 tons per hectare. But economically the yield achieved is still profitable and feasible because it is compensated by the high chili selling price.

3. Constraints Utilization of Tin Mined Land

Constraints faced in the use of tin mining land for chili farming include physical land constraints, labor availability, the cost of fertigation installations and pest and disease control. Those constraints should be solved in order to chili cultivation on tin mined land can be feasible and profitable.

3.1. Physical Constraints

Tin mined land consist of 84% sand fraction, whereas clay fraction 3% only. This condition causes poor soil properties both of physical, chemical and biological properties. From physical aspect, soil low slow drainage pores (SDP) conversely high in fast drainage pores (FDP). That’s mean the soil has a low water holding capacity (WHC) so that soil moisture will loss very fast. Incorporating manure and biochar tends to increase water holding capacity, so that irrigation was more efficient and risk of plant water stress decreased. Among parameters observed, only water holding capacity showed...
significant different due to manure and biochar treatment. Chili plant is very susceptible to water stress, therefore watering effort should be done in order chili plant do not experiences water stress. Drip irrigation is one effort to provide water continuously and increase water use efficiency. [5] also stated that the fertigation system can increase the efficiency of water and fertilizer use.

From chemical aspect, tin mined land has low nutrient holding capacity and low nutrients availability. Low CEC causes low efficiency use of fertilizer because nutrients that provide through fertilization will loss very fast due to leaching. Inherently, tin mined land consist of quartz sand so that poor in both of macro and micro nutrients. All nutrients needed by plant for optimum growth should be provide. Conventional NPK could not meet plant requirement, so that chili cultivation on such land should be provide special fertilizer formula than contain most of nutrient needed. AB-mix fertilizer formula is a special for apply through drip irrigation network then called fertigation. Fertigation system will increase efficiency use of water and fertilizer.

3.2. Lack of Labour
Conventional chili cultivation is labor intensive, meanwhile local labor availability is very limited. Most of people at Bangka prefer work in tin mining because they received much more wages compared to work on farm. Worker wages also much more higher than other region. Therefore, it is consider to use of farming tools to facilitate worker work faster and more efficient. Water management aspect is one of intensive activities because soil moisture loss on tin mined soil much faster than soil in general. Therefore, it is consider to use drip irrigation system in order to minimize use of labor. Besides that, drip irrigation network can also use for fertilizers application, then called fertigation system. The costs for purchasing equipment and installing a fertigation network are indeed quite high. But the equipment can be used for several years. So that if calculated for one planting season, the cost is still affordable and economical

3.3. Pest and Diseases
The main constraints in chilli cultivation is the attack of pests and diseases that can substantially decreased crop yields. The common pests that attack the chili plants are fruit flies, thrips and aphids. Control of fruit flies in addition to spraying, is also done by setting traps that contain pheromone methyl eugenol. Aphids and thrips can be controlled by installing plastic mulch and spraying insecticides. The common diseases that attack chili plants in tin mined land are curly virus, anthracnose and wilt disease. Viral diseases can be controlled by planting disease-free seeds and controlling the vectors. Anthracnose disease can be controlled by using resistant varieties and spraying fungicides regularly.

4. Conclusion
1. Chili cultivation on tin mined land has good prospects because there are many lands available, promising markets and farming technologies available.
2. The main constraints faced include poor soil properties, pest and disease infestation and lack of labor
3. Poor soil properties can be solve by application of manure mixed with biochar to improve the water holding capacity, cations exchange capacity, and nutrient availability
4. The application of fertigation technology can increased chili yield and improving the efficiency of watering and fertilizer use.
5. The productivity of chilies planted on tin mined land is still low, but this is compensated by high selling prices so that it is still profitable and feasible to be cultivated
References

[1] Asmarhansyah D, Rusmawan and Muzammil 2012 Soil chemistry and yield of maize as influenced by different levels of fertilizer in ex-tin land Central Bangka, Kepulauan Bangka Belitung in International Maize Conference Agribusiness of Maize- Livestock Integration. Gorotalo, 21 – 23 November 2012. Pp 205 – 208.

[2] Ang L H, Seel W E and Mullins C 1999 Microclimate and water status of sand tailing at an-examining site in Peninsular Malaysia J of Tropical Forest Science 1(1) 157-170.

[3] Awang K 1988 Tin tailings and their possible reclamation in Malaysia in Adisoemanto S ed. in Regional Workshop on Ecodevelopment Process for degraded land resources in Southeast Asia, Bogor 23-25 August 1988.

[4] Bapedalda Provinsi Kepulauan Bangka Belitung 2007 Kondisi kerusakan lingkungan hidup di Provinsi Kepulauan Bangka Belitung (Pangkalpinang: Bapedalda Provinsi Kepulauan Bangka Belitung)

[5] Chantai S and Wonprasad 2016 Effects of Fertigation and Water Application Frequency on Yield, Water and Fertilizer Use Efficiency of Chili (Capsicum annuum L.) Int’l Journal of Research in Chemical, Metallurgical and Civil Engg. (IJRCMCE) 3(2) 209-213

[6] Hanura 2005 Perbaikan sifat kimia bahan tailing asal lahan pasca penambangan timah yang diberi kompos dan pengaruhnya terhadap pertumbuhan tanaman kedelai. Tesis. Program Studi Ilmu Tanaman Program Pascasarjana Universitas Sriwijaya (tidak dipublikasikan).

[7] Nurida N L, Dariah A and Rachman A 2013 Peningkatan kualitas tanah dengan pembenah tanah biochar limbah pertanian Jurnal Tanah dan Iklim 37 (2) 69 – 78.

[8] Nurida N L 2014 Potensi pemanfaatan biochar untuk rehabilitasi lahan kering di Indonesia. Jurnal Sumberdaya Lahan. Karakteristik dan Variasi Sumberdaya Lahan Pertanian 57 – 68.

[9] Nurida N L, Dariah A, Sutono S 2015 Pembenah tanah alternatif untuk meningkatkan produktivitas tanah dan tanaman kedelai di lahan kering masam Jurnal Tanah dan Iklim 39(2) 99 – 108.

[10] Gerard C, Jubaedah, Neneng L, Sarah E H, Vegard M, Ludovica S, Jan M 2018 Fading positive effect of biochar on crop yield and soil acidity during five growth seasons in an Indonesian Ultisol. Science of the Total Environment 634 (208) 561 – 568.

[11] Novak J M, Lima J, Xing B, Gaskin J W, Steiner J, Das K, Ahmeda M, Rehreh D, Watts D W and Bussher W J 2009 Carakerization of designer biochar produce at different temperature and their effect on the loamy sand. Annals of Environmental Science 3 (1) 195 – 206.

[12] Sukartono and Utomo W H 2012 Peranan biochar sebagai pembenah tanah pada pertanaman jagung di tanah lempung berpasir (sandy loam) semiarid tropis Lombok Utara Jurnal Penelitian Ilmu-Ilmu Kelaman: Buana Sains 12(1) 91-98.

[13] Yu Ok-You, R Brian and Sam S 2013 Impact of biochar on the water holding capacity of loamy sand soil. IJEE 4 44 http://www.journal.ijee.co/content/4/1/44. (24 Mei 2014)

[14] Subardja D A, Kasno, Sutono and Sosiawan H 2012 Identifikasi dan karakterisasi lahan bekas tambang timah untuk pencetakan sawah baru di Perlang, Bangka Tengah in Preceeding of Seminar Nasional Sumberdaya Lahan Pertanian (Bogor, 30 November - 1 Desember 2010) pp109 -122.

[15] Santi R 2005 Pertumbuhan Nilam (Pogostemon cablin Benth) pada sandy tailing asal lahan pasca penambangan timah yang diberi kompos dan tanah kupasan (overburden). Tesis. Program Studi Ilmu Tanaman Program Pascasarjana Universitas Sriwijaya (tidak dipublikasikan).

[16] Subiksa I G M, Adnyana M O, Haryati U and Husnain 2019 Effect of Fertilizers Application through Fertigation System on Chili Cultivation on Tin Mined Land in Bangka Island. International Journal of Research Studies in Agricultural Sciences 5 (5) 15-26

[17] Tanpibal V and Sahunalu P 1989 Characteristics and management of tin mine tailing in Thailand. Soil Technology 2 17-26.